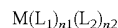




US 20160028024A1

(19) **United States**(12) **Patent Application Publication**
DAS et al.(10) **Pub. No.: US 2016/0028024 A1**(43) **Pub. Date: Jan. 28, 2016**(54) **ORGANOMETALLIC COMPOUND AND
ORGANIC LIGHT-EMITTING DEVICE
INCLUDING THE SAME**(71) Applicants: **Samsung Electronics Co., Ltd.**,
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(KR)(21) Appl. No.: **14/713,435**(22) Filed: **May 15, 2015**(30) **Foreign Application Priority Data**Jul. 24, 2014 (KR) 10-2014-0094156
Jan. 13, 2015 (KR) 10-2015-0006120**Publication Classification**(51) **Int. Cl.**
H01L 51/00 (2006.01)
C09K 11/06 (2006.01)
C07F 15/00 (2006.01)(52) **U.S. Cl.**
CPC **H01L 51/0085** (2013.01); **C07F 15/0033**
(2013.01); **C09K 11/06** (2013.01); **C09K**
2211/185 (2013.01); **C09K 2211/1074**
(2013.01); **H01L 51/5012** (2013.01)(57) **ABSTRACT**

An organometallic compound represented by Formula 1:



Formula 1

wherein in Formula 1, L_1 is a divalent ligand represented by
Formula 2, L_2 is selected from a monovalent organic ligand, a
divalent organic ligand, and trivalent organic ligand, and L_2 is
not a ligand represented by Formula 2;

Formula 2

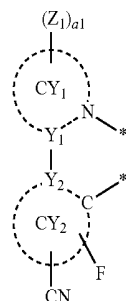
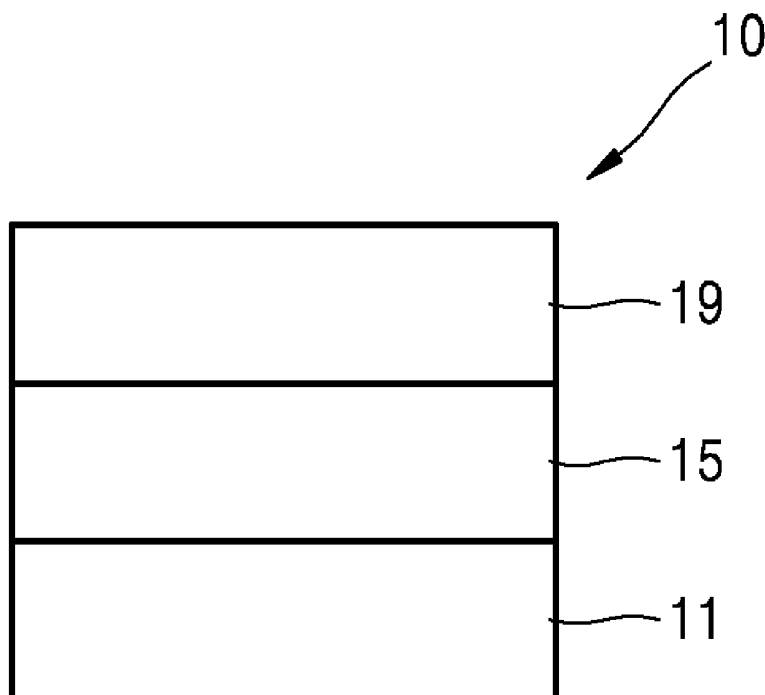
wherein in Formulae 1 and 2, M, CY_1 , CY_2 , Y_1 , Y_2 , Z_1 , a_1 , n_1 ,
and n_2 are the same as described in the specification.

FIG. 1

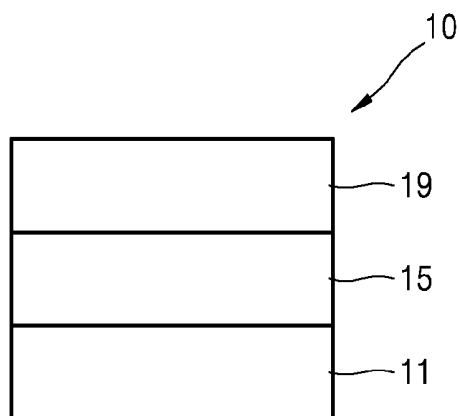


FIG. 2

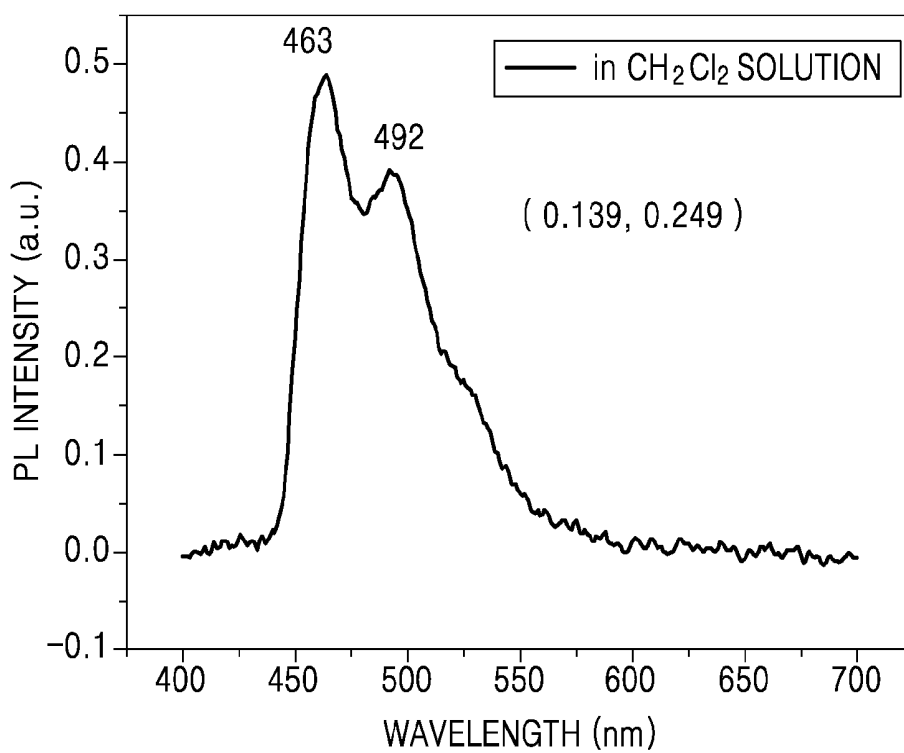


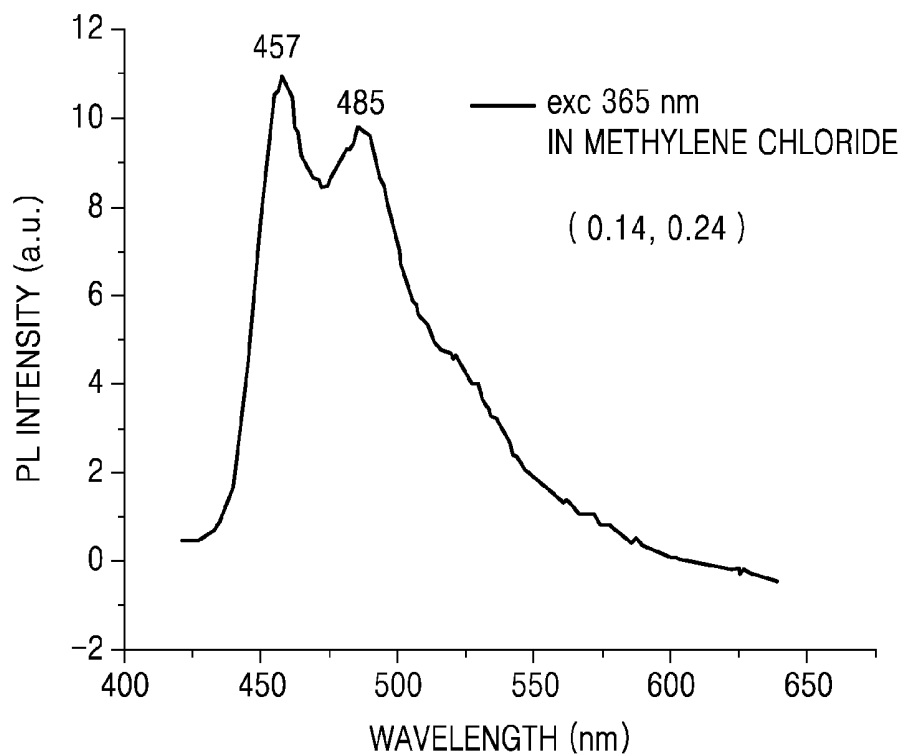
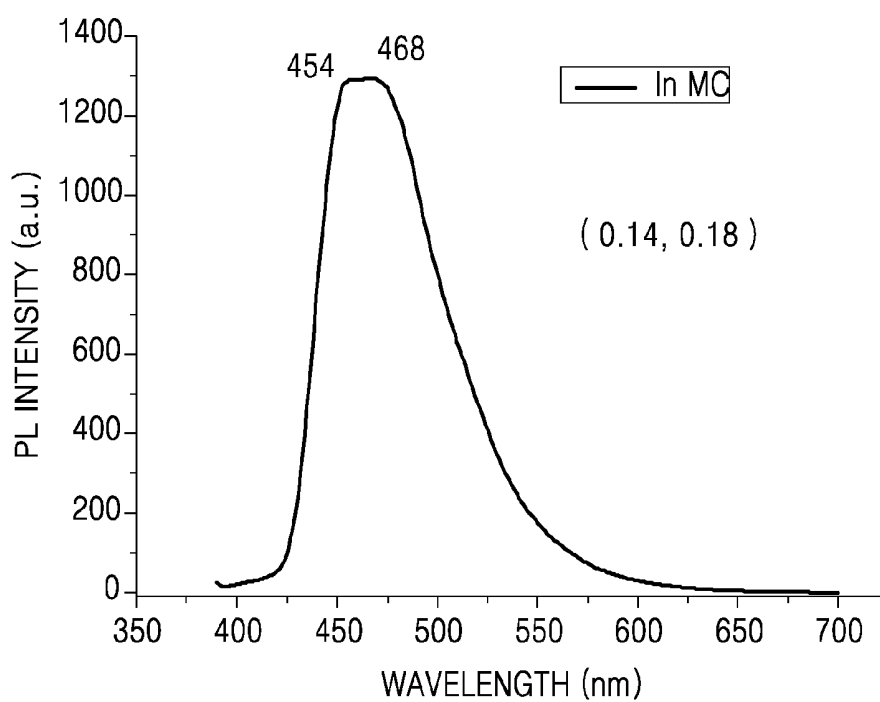
FIG. 3**FIG. 4**

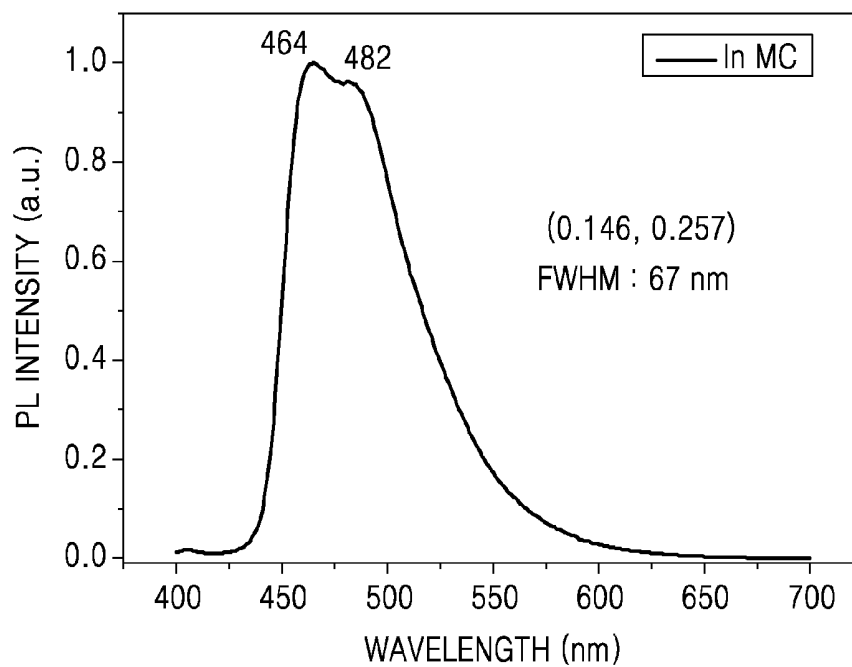
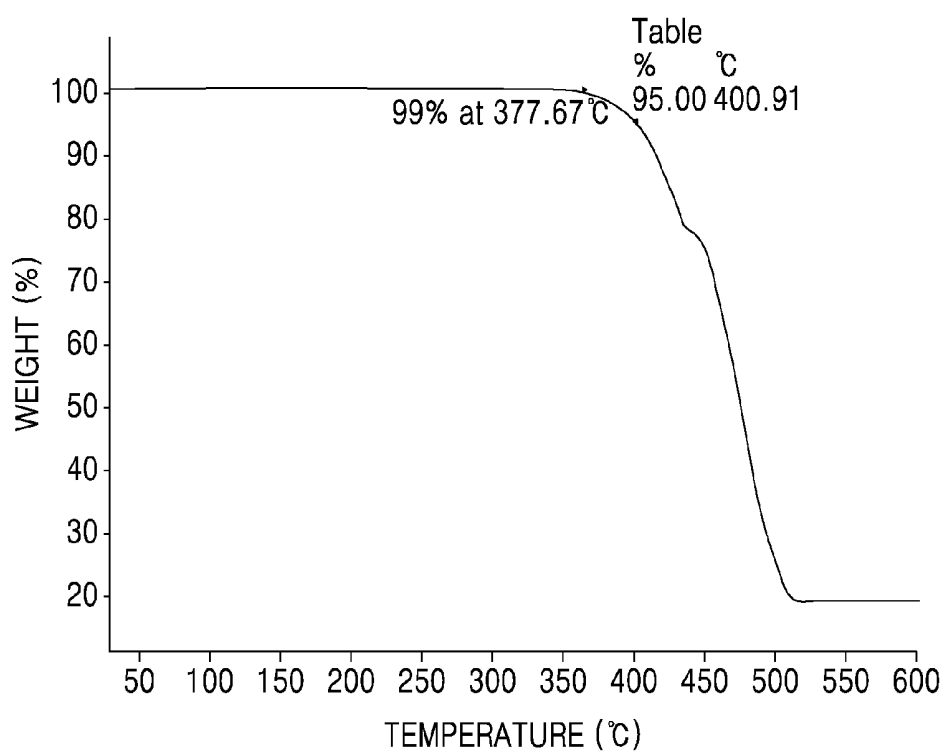
FIG. 5**FIG. 6**

FIG. 7

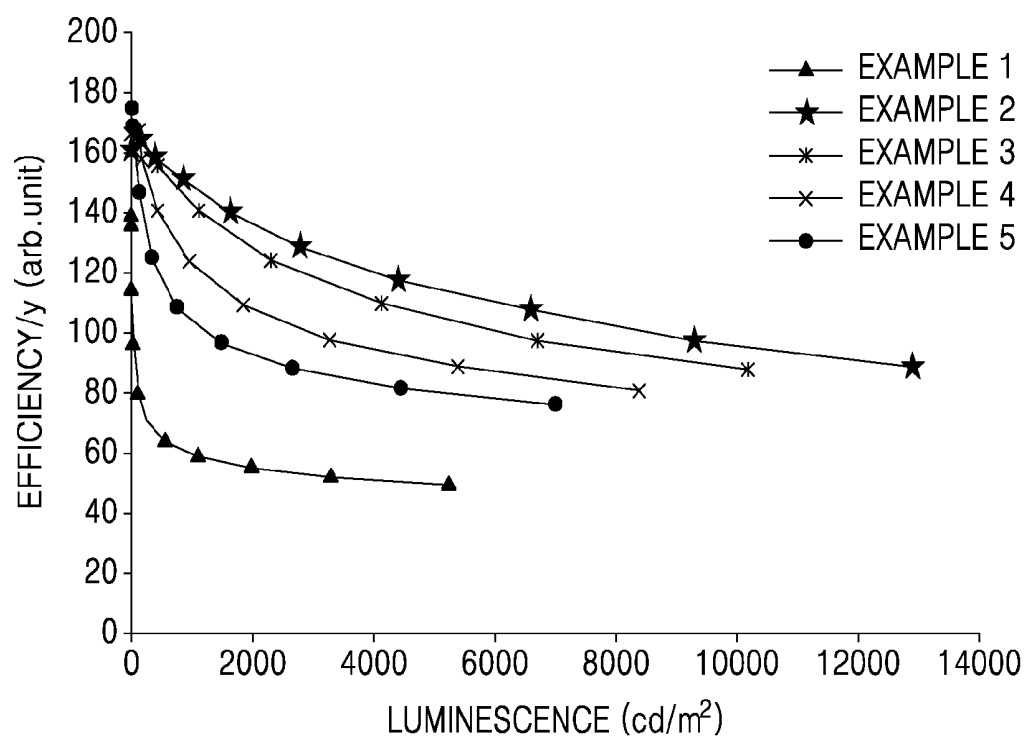
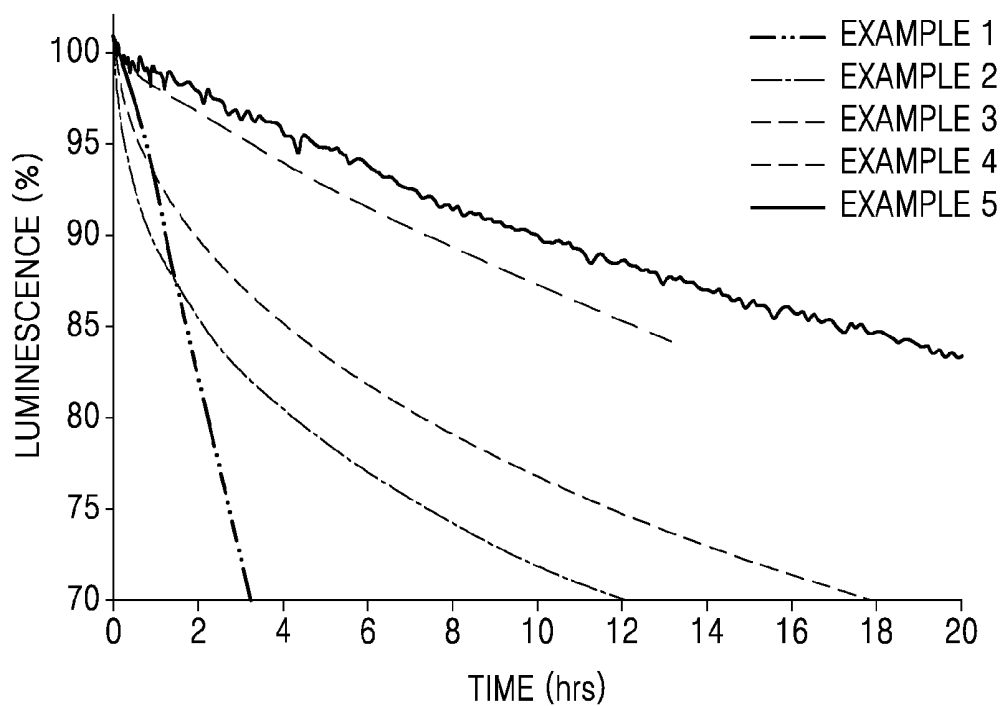


FIG. 8



ORGANOMETALLIC COMPOUND AND ORGANIC LIGHT-EMITTING DEVICE INCLUDING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to Korean Patent Application Nos. 10-2014-0094156, filed on Jul. 24, 2014, and 10-2015-0006120, filed on Jan. 13, 2015, in the Korean Intellectual Property Office, and all the benefits accruing therefrom under 35 U.S.C. §119, the contents of which are incorporated herein in the it 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 that is disposed between the anode and the cathode and includes an emission layer. 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 are recombined in the emission layer to produce excitons. These excitons change from an excited state to a ground state, thereby generating light.

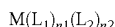
[0007] Various types of organic light emitting devices are known. However, there still remains a need in OLEDs having low driving voltage, high efficiency, high brightness, and long lifespan.

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:



Formula 1

[0011] wherein in Formula 1,

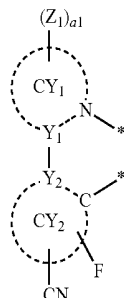
[0012] L_1 is a divalent ligand represented by Formula 2,

[0013] L_2 is selected from a monovalent organic ligand, a

divalent organic ligand, and trivalent organic ligand, and

[0014] L_2 is not a ligand represented by Formula 2;

Formula 2



[0015] wherein in Formula 2,

[0016] M is selected from Ir, Pt, Os, Ti, Zr, Hf, Eu, Tb, and Tm;

[0017] Y_1 to Y_2 are each independently C or N;

[0018] Y_1 and N are linked to each other via a single bond or a double bond, and Y_2 and C are linked to each other via a single bond or a double bond

[0019] CY_1 is a C_1 - C_{60} heterocyclic group;

[0020] CY_2 is selected from a C_5 - C_{60} cyclic group and a C_1 - C_{60} heterocyclic group;

[0021] CY_1 and CY_2 are optionally additionally linked to each other via a first linking group;

[0022] Z_1 is selected from a hydrogen, a deuterium, a hydroxyl 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 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, $-N(Q_1)(Q_2)$, $-Si(Q_3)(Q_4)(Q_5)$, and $-B(Q_6)(Q_7)$;

[0023] a_1 is an integer selected from 1 to 5, provided that when a_1 is two or more, groups Z_1 are each identical or different;

[0024] n_1 is an integer selected from 1 to 3, provided that when n_1 is two or more, groups L_1 are each identical or different;

[0025] n_2 is an integer selected from 0 to 4, provided that when n_2 is two or more, groups L_2 are each identical or different;

[0026] * and *' in Formula 1 each indicates a binding site to M;

[0027] at least one of substituents of the substituted C_1 - C_{60} alkyl group, the substituted C_2 - C_{60} alkenyl group, the substituted C_2 - C_{60} alkynyl group, the substituted C_1 - C_{60} alkoxy group, the substituted C_3 - C_{10} cycloalkyl group, the substi-

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

[0028] 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, 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;

[0029] 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, 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}), and —B(Q_{16})(Q_{17});

[0030] 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;

[0031] 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 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, 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}), and —B(Q_{26})(Q_{27}); and

[0032] —N(Q_{31})(Q_{32}), —Si(Q_{33})(Q_{34})(Q_{35}), and —B(Q_{36})(Q_{37}),

[0033] wherein Q_1 to Q_7 , Q_{11} to Q_{17} , Q_{21} to Q_{27} , and Q_{31} to Q_{37} are each independently selected from a hydrogen, 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, 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, and a monovalent non-aromatic condensed heteropolycyclic group.

[0034] According to an aspect of another exemplary embodiment, an organic light-emitting device includes:

[0035] a first electrode;

[0036] a second electrode; and

[0037] an organic layer disposed between the first electrode and the second electrode,

[0038] wherein the organic layer includes an emission layer and at least one selected from the organometallic compound represented by Formula 1.

[0039] The organometallic compound is included in the emission layer, the organometallic compound included in the emission layer acts as a dopant, and the emission layer further includes a host.

BRIEF DESCRIPTION OF THE DRAWINGS

[0040] These and/or other aspects will become apparent and more readily appreciated from the following description of the exemplary embodiments, taken in conjunction with the accompanying drawings in which:

[0041] FIG. 1 is a schematic view of an organic light-emitting device according to an embodiment;

[0042] FIG. 2 is a graph of photoluminescent (PL) intensity (arbitrary units, a. u.) versus wavelength (nanometers, nm), which is a photoluminescent (PL) spectrum of Compound 1;

[0043] FIG. 3 is a graph of photoluminescent (PL) intensity (arbitrary units, a. u.) versus wavelength (nanometers, nm), which is a PL spectrum of Compound 2;

[0044] FIG. 4 is a graph of photoluminescent (PL) intensity (arbitrary units, a. u.) versus wavelength (nanometers, nm), which is a PL spectrum of Compound 3;

[0045] FIG. 5 is a graph of photoluminescent (PL) intensity (arbitrary units, a. u.) versus wavelength (nanometers, nm), which is a PL spectrum of Compound 4;

[0046] FIG. 6 is a graph of percent weight (percent, %) versus temperature (degrees Centigrade, ° C.), representing a TGA (Thermo Gravimetric Analysis) data of Compound 1;

[0047] FIG. 7 is a graph of efficiency (arbitrary units, a. u.) versus luminescence (candelas per square meter) illustrating the relationship between brightness and efficiency/y of organic light-emitting devices of Example 1 to 5; and

[0048] FIG. 8 is a graph of luminescence (percent, %) versus time (hours, hrs) illustrating the relationship between time and brightness of organic light-emitting devices of Example 1 to 5.

DETAILED DESCRIPTION

[0049] 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.

[0050] 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.

[0051] 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.

[0052] 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.

[0053] 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.

[0054] Spatially relative terms, such as “beneath,” “below,” “lower,” “above,” “upper” and the like, may be used herein for ease of description to describe one element or feature’s relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as “below” or “beneath” other elements or features would then be oriented “above” the other elements or features. Thus, the exemplary term “below” can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

[0055] “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 $\pm 30\%$, 20% , 10% , 5% of the stated value.

[0056] 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 invention 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.

[0057] 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.

[0058] An organometallic compound according to an embodiment is represented by Formula 1 below:



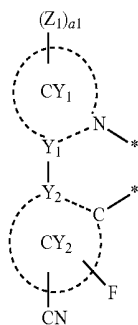
[0059] wherein in Formula 1,

[0060] L_1 may be a divalent ligand represented by Formula 2, and

[0061] L_2 may be selected from a monovalent organic ligand, a divalent organic ligand, and trivalent organic ligand, and

[0062] L_2 may not be a ligand represented by Formula 2;

Formula 2



[0063] * and *' in Formula 2 indicate a binding site to M in Formula 1.

[0064] M in Formula 1 may be selected from iridium (Ir), platinum (Pt), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), and thulium (Tm).

[0065] In some embodiments, M in Formula 1 may be Ir or Pt.

[0066] Y_1 and Y_2 in Formula 2 may be each independently carbon (C) or nitrogen (N).

[0067] In some embodiments, Y_1 and Y_2 may be a carbon, but they are not limited thereto.

[0068] In Formula 2, Y_1 and N may be linked to each other via a single bond or a double bond, and Y_2 and C may be linked to each other via a single bond or a double bond.

[0069] In Formula 2, CY_1 may be a C_1 - C_{60} heterocyclic group, and CY_2 may be a C_5 - C_{60} cyclic group or C_1 - C_{60} heterocyclic group.

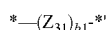
[0070] In some embodiments, in Formula 2, CY_1 may be selected from a pyrrole, an imidazole, a pyrazole, a thiazole, an isothiazole, an oxazole, an isoxazole, a triazole, a pyridine, a pyrazine, a pyrimidine, a pyridazine, a quinoline, an isoquinoline, a benzoquinoline, a quinoxaline, a quinazoline, a benzimidazole, a benzoxazole, an isobenzoxazole, a triazole, a tetrazole, an oxadiazole, and a triazine,

[0071] CY_2 may be selected from a benzene, a naphthalene, a fluorene, a spiro-fluorene, an indene, a pyrrole, a thiophene, a furan, an imidazole, a pyrazole, a thiazole, an isothiazole, an oxazole, an isoxazole, a triazole, a pyridine, a pyrazine, a pyrimidine, a pyridazine, a quinoline, an isoquinoline, a benzoquinoline, a quinoxaline, a quinazoline, a carbazole, a benzimidazole, a benzofuran, a benzothiophene, an isobenzothiophene, a benzoxazole, an isobenzoxazole, a triazole, a tetrazole, an oxadiazole, a triazine, a dibenzofuran, and a dibenzothiophene.

[0072] In some embodiments, in Formula 2, CY_1 may be an imidazole, a triazole, or a pyridine, and CY_2 may be a benzene or a pyridine, but they are not limited thereto.

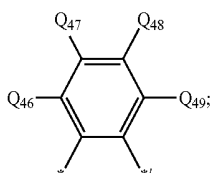
[0073] In some embodiments, in Formula 2, CY_1 may be an imidazole or a pyridine, and CY_2 may be a benzene.

[0074] In Formula 2, CY_1 and CY_2 may be additionally linked to each other by the first linking group. The first linking group may be represented by Formula 6 below.



Formula 6

[0075] wherein in Formula 6, Z_{31} may be selected from $*-O-*$, $*-S-*$, $*-N(Q_{41})-*$, $*-C(Q_{44})=C(Q_{45})-*$, and



[0076] Q_{41} and Q_{44} to Q_{49} may be each independently selected from

[0077] a hydrogen, 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, 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;

[0078] 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, $-F$, $-Cl$, $-Br$, $-I$, 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, and a monovalent non-aromatic condensed heteropolycyclic group;

[0079] 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; and

[0080] 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 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, 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, and a monovalent non-aromatic condensed heteropolycyclic group, and

[0081] $b1$ may be selected from an integer selected from 1 to 10, provided that when $b1$ is two or more, groups Z_{31} may be identical or different.

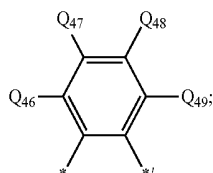
[0082] In some embodiments, in Formula 6, Q_{41} to Q_{49} may be each independently selected from

[0083] a hydrogen, 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, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

[0084] a C_1 - C_{20} alkyl group and a C_1 - C_{20} 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, a phosphoric acid group or a salt thereof, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group; and

[0085] a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group; but they are not limited thereto.

[0086] In some embodiments, in Formula 2, CY_1 and CY_2 may be linked to each other via a single bond or the first linking group, and the first linking group may be represented by $*-C(Q_{44})=C(Q_{45})-*$ or



(that is, in Formula 6, $b1=1$), wherein Q_{44} to Q_{49} may be each independently selected from a hydrogen, a C_1 - C_{10} alkyl group and a C_1 - C_{10} alkoxy group, but they are not limited thereto.

[0087] In Formula 2, Z_1 may be selected from a hydrogen, a deuterium, a hydroxyl 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 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, $-N(Q_1)(Q_2)$, $-Si(Q_3)(Q_4)(Q_5)$, and $-B(Q_6)(Q_7)$. Q_1 to Q_7 may be understood by referring to descriptions to be provided herein.

[0088] In some embodiments, Z_1 in Formula 2 may be selected from

[0089] a hydrogen, a deuterium, a hydroxyl 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_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

[0090] a C_1 - C_{20} alkyl group and a C_1 - C_{20} 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, a phosphoric acid group or a salt thereof, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group;

[0091] 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 isooxazolyl 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 isobenzooxazolyl 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;

[0092] 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 isobenzooxazolyl 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, $-F$, $-Cl$, $-Br$, $-I$, 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_{20} alkyl group, a C_1 - C_{20} alkoxy 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 isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and $-Si(Q_{33})(Q_{34})(Q_{35})$; and

[0093] $-Si(Q_3)(Q_4)(Q_5)$;

[0094] Q_3 to Q_5 and Q_{33} to Q_{35} may be each independently selected from a hydrogen, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy 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 isobenzooxazolyl 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.

[0095] In some embodiments, in Formula 2, Z_1 may be selected from

[0096] a hydrogen, a nitro group, a methyl group, an ethyl group, a propyl 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-decanyl group, an isodecanyl group, a sec-decanyl group, a tert-decanyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, and a pentoxy group;

[0097] a methyl group, an ethyl group, a propyl 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-decanyl group, an isodecanyl group, a sec-decanyl group, a tert-decanyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, and a pentoxy group, each substituted with at least one selected from —F, a cyano group, and a nitro group;

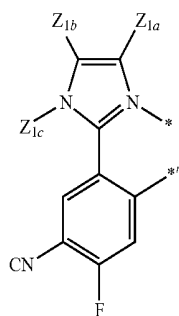
[0098] a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, and a dibenzofuran group;

[0099] a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group and a dibenzofuran group, each substituted with at least one selected from —F, a cyano group, a nitro group, a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, and —Si(Q_{33})(Q_{34})(Q_{35}); and

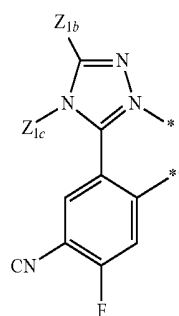
[0100] —Si(Q_3)(Q_4)(Q_5);

[0101] wherein Q_3 to Q_5 and Q_{33} to Q_{35} may be each independently selected from a hydrogen, a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, and a triazinyl group, but they are not limited thereto.

[0102] In some embodiments, in Formula 1, L_1 may be selected from ligands represented by Formulae 2A to Formula 2G.

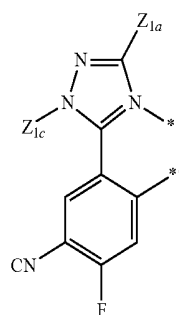


Formula 2A

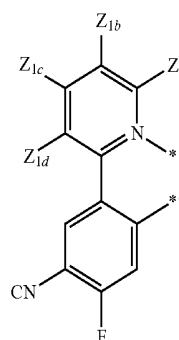


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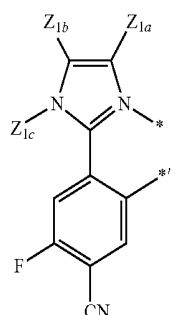
Formula 2B



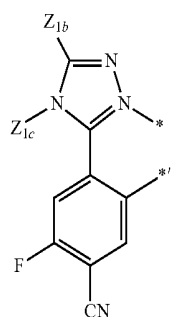
Formula 2C



Formula 2D

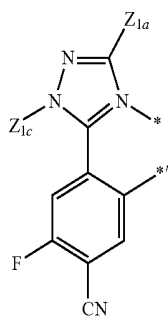


Formula 2E

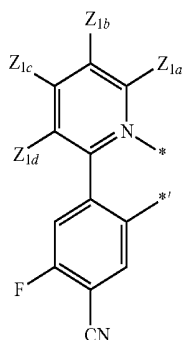


Formula 2F

-continued



Formula 2G



Formula 2H

[0103] Descriptions for Z_{1a} to Z_{1d} in Formulae 2A to 2H may be each independently the same as defined in connection with Z_1 herein.

[0104] In some embodiments, in Formulae 2A to 2H, Z_{1a} to Z_{1d} may be each independently selected from

[0105] a hydrogen, a nitro group, a methyl group, an ethyl group, a propyl 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-decanyl group, an isodecanyl group, a sec-decanyl group, a tert-decanyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, and a pentoxy group;

[0106] a methyl group, an ethyl group, a propyl 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-decanyl group, an isodecanyl group, a sec-decanyl group, a tert-decanyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, and a pentoxy group, each substituted with at least one selected from —F, a cyano group, and a nitro group;

[0107] a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, and a dibenzofuran group;

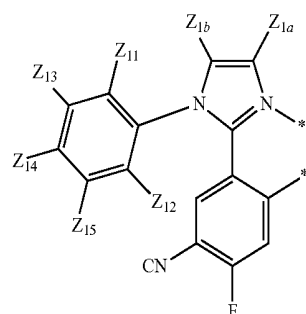
[0108] a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group and a dibenzofuran group, each substituted with at least one selected from —F, a

cyano group, a nitro group, a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, and —Si(Q_{33})(Q_{34})(Q_{35}); and

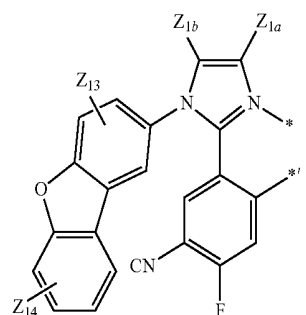
[0109] —Si(Q_3)(Q_4)(Q_5);

[0110] wherein Q_3 to Q_5 and Q_{33} to Q_{35} may be each independently selected from a hydrogen, a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, and a triazinyl group, but they are not limited thereto.

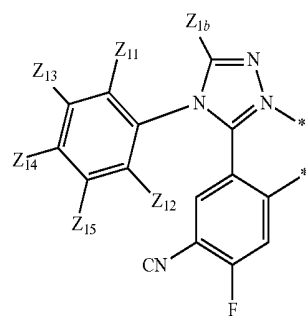
[0111] In some embodiments, L_1 in Formula 1 may be selected from ligands represented by Formulae 2A-1 to 2C-1 and 2A-2 to 2C-2:



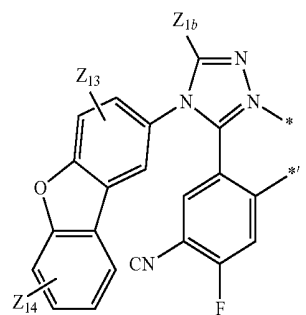
Formula 2A-1



Formula 2A-2

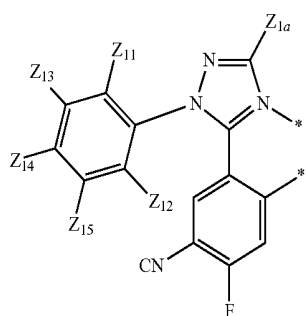


Formula 2B-1

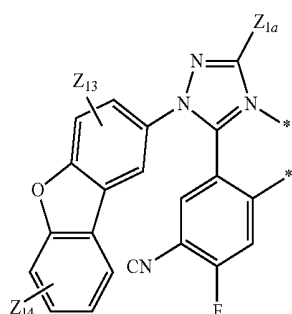


Formula 2B-2

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Formula 2C-1



Formula 2C-2

[0112] wherein in Formulae 2A-1 to 2C-1 and 2A-2 to 2C-2,

[0113] Z_{1a} , Z_{1b} , and Z_{11} to Z_{15} are each independently selected from a hydrogen, a nitro group, a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, and $-\text{Si}(\text{Q}_{33})(\text{Q}_{34})(\text{Q}_{35})$,

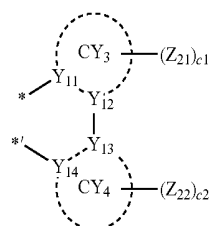
[0114] wherein Q_{33} to Q_{35} may be each independently selected from a hydrogen, a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, and a triazinyl group, but they are not limited thereto.

[0115] In some embodiments, in Formula 1, L_1 may be selected from ligands represented by Formulae 2A-1 to 2C-1, wherein in Formulae 2A-1 to 2C-1, Z_{11} and Z_{12} may be each independently selected from a nitro group, a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, and $-\text{Si}(\text{Q}_{33})(\text{Q}_{34})(\text{Q}_{35})$.

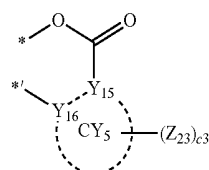
[0116] a_1 in Formula 2 indicates the number of groups Z_1 , and a_1 may be an integer selected from 1 to 5. For example, a_1 may be 1, 2 or 3. When a_1 is two or more, groups Z_1 may be identical or different.

[0117] In Formula 1, L_2 may be selected from any monovalent organic ligand, any divalent organic ligand, and any trivalent organic ligand, but L_2 is not a ligand represented by Formula 2. Accordingly, ligands which satisfies Formula 2 are excluded from those represented by Formulae 3-1 and 4-1 to 4-72. For example, L_2 may be different from L_1 in Formula 1.

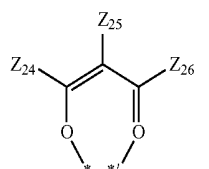
[0118] In some embodiments, L_2 in Formula 1 may be selected from ligands represented by Formulae 3-1 to 3-7 below:



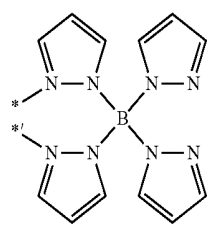
Formula 3-1



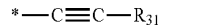
Formula 3-2



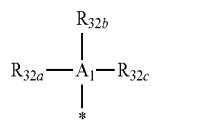
Formula 3-3



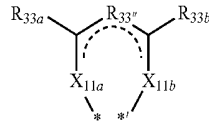
Formula 3-4



Formula 3-5



Formula 3-6



Formula 3-7

[0119] wherein in Formulae 3-1 to 3-7,

[0120] Y_{11} to Y_{16} are each independently carbon (C) or nitrogen (N);

[0121] CY_3 to CY_5 may be each independently selected from a C_5 - C_{60} cyclic group and a C_1 - C_{60} heterocyclic group,

[0122] Z_{21} to Z_{26} , R_{31} , R_{32a} , R_{32b} , R_{32c} , R_{33a} , R_{33b} , and R_{34} to R_{38} may be each independently selected from a hydrogen, a deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, 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, $-\text{SF}_5$, 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 C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, and —Si(Q₄₁)(Q₄₂)(Q₄₃);

[0123] c1 to c3 may be each independently an integer selected from 1 to 5;

[0124] A₁ may be P or As;

[0125] X_{11a} and X_{11b} may be each independently selected from N, O, N(R₃₄), P(R₃₅)(R₃₆), and As(R₃₇)(R₃₈);

[0126] R_{33a} may be selected from a single bond, a double bond, a substituted or unsubstituted C₁-C₅ alkylene group, and a substituted or unsubstituted C₂-C₅ alkenylene group;

[0127] wherein Q₄₁ to Q₄₃ may be each independently selected from a hydrogen, 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, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

[0128] * and *' each indicates a binding site to M in Formula 1.

[0129] In some embodiments, CY₃ to CY₅ may be each independently selected from a benzene, a naphthalene, a fluorene, a spiro-fluorene, an indene, a pyrrole, a thiophene, a furan, an imidazole, a pyrazole, a thiazole, an isothiazole, an oxazole, an isooxazole, a pyridine, a pyrazine, a pyrimidine, a pyridazine, a quinoline, an isoquinoline, a benzoquinoline, a quinoxaline, a quinazoline, a carbazole, a benzoimidazole, a benzofuran, a benzothiophene, an isobenzothiophene, a benzoxazole, an isobenzoxazole, a triazole, a tetrazole, an oxadiazole, a triazine, a dibenzofuran, and a dibenzothiophene.

[0130] Z₂₁ to Z₂₆, R₃₁, R_{32a}, R_{32b}, R_{32c}, R_{33a}, R_{33b}, and R₃₄ to R₃₈ may be each independently selected from

[0131] a hydrogen, 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, a phosphoric acid group or a salt thereof, —SF₅, a C₁-C₂₀ alkyl group, and a C₁-C₂₀ alkoxy group;

[0132] a C₁-C₂₀ alkyl group and a C₁-C₆₀ 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, a phosphoric acid group or a salt thereof, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group;

[0133] 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 isooxazolyl 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 benzooxazolyl group, an isobenzooxazolyl 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;

[0134] 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 isooxazolyl 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 benzooxazolyl group, an isobenzooxazolyl 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, and an imidazopyridinyl 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, a phosphoric acid group or a salt thereof, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy 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 isooxazolyl 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 benzooxazolyl group, an isobenzooxazolyl 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

[0135] —Si(Q₄₁)(Q₄₂)(Q₄₃);

[0136] c1 to c3 may be each independently selected from 1, 2, and 3;

[0137] X_{11a} and X_{11b} may be each independently selected from O, P(R₃₅)(R₃₆), and As(R₃₇)(R₃₈);

[0138] R_{33} may be selected from a single bond, a double bond, a substituted or unsubstituted C_1 - C_2 alkylene group, and a substituted or unsubstituted C_2 alkenylene group;

[0139] wherein Q_{41} to Q_{43} may be each independently selected from a hydrogen, a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, and a triazinyl group, but they are not limited thereto.

[0140] In some embodiments, in Formula 1, L_2 may be selected from a ligand represented by Formulae 3-1 to Formula 3-4 above.

[0141] CY_3 may be selected from a pyridine, an imidazole, a pyrazole, a triazole, and a tetrazole;

[0142] CY_4 may be selected from a benzene, a pyridine, a pyrimidine, and a triazine;

[0143] CY_5 may be selected from a benzene and a pyridine;

[0144] Y_{11} may be N;

[0145] Y_{12} , Y_{13} , and Y_{15} may be C;

[0146] Y_{14} and Y_{16} may be each independently selected from N and C;

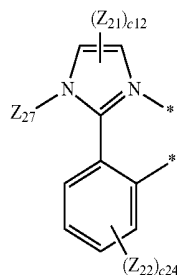
[0147] Z_{21} to Z_{26} may be each independently selected from

[0148] a hydrogen, —F, a cyano group, a nitro group, — SF_5 , a methyl group, an ethyl group, a propyl 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-decanyl group, an isodecanyl group, a sec-decanyl group, a tert-decanyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

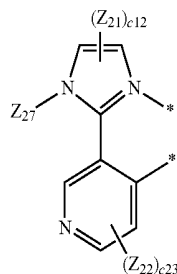
[0149] a methyl group, an ethyl group, a propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an isohexyl group, a sec-hexyl group, a tert-hexyl group, 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-decanyl group, an isodecanyl group, a sec-decanyl group, a tert-decanyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from —F, a cyano group, and a nitro group;

[0150] c_1 to c_3 may be each independently 1, 2 or 3, but are not limited thereto.

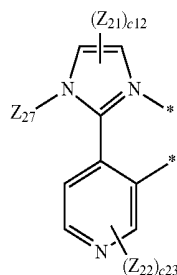
[0151] In some embodiments, in Formula 1, L_2 may be selected from a ligand represented by Formulae 4-1 to 4-106 below, but is not limited thereto:



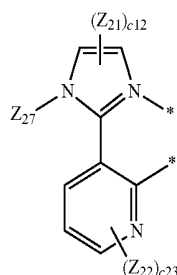
Formula 4-1



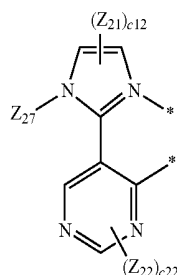
Formula 4-2



Formula 4-3

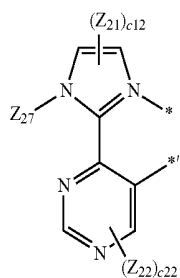


Formula 4-4

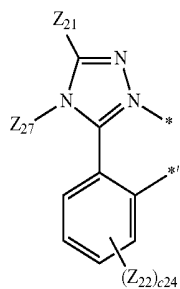


Formula 4-5

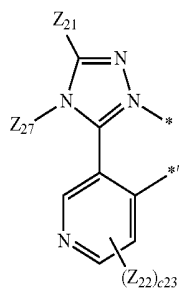
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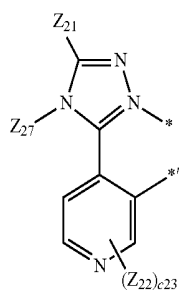
Formula 4-6



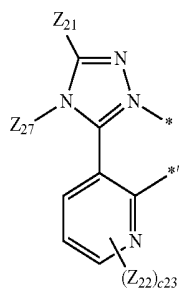
Formula 4-7



Formula 4-8

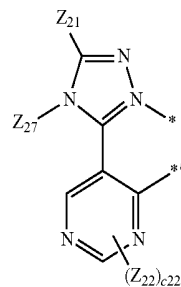


Formula 4-9

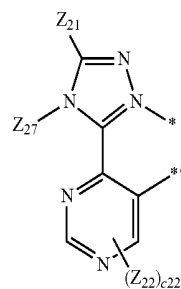


Formula 4-10

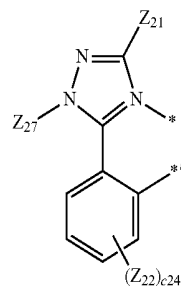
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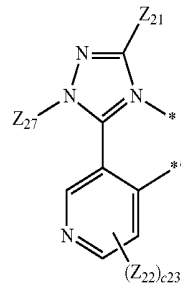
Formula 4-11



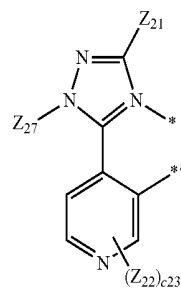
Formula 4-12



Formula 4-13

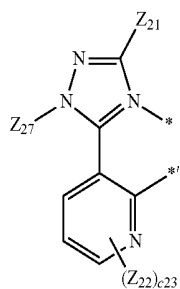


Formula 4-14

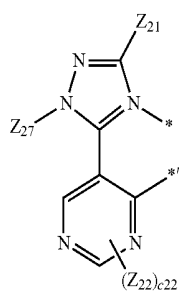


Formula 4-15

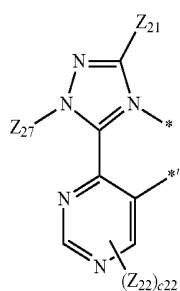
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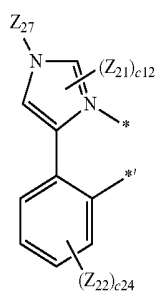
Formula 4-16



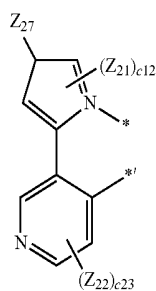
Formula 4-17



Formula 4-18

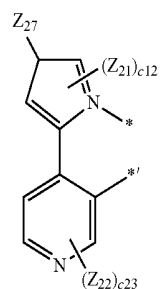


Formula 4-19

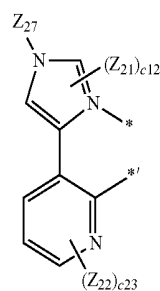


Formula 4-20

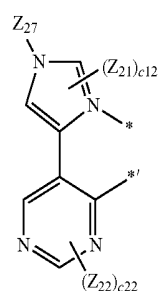
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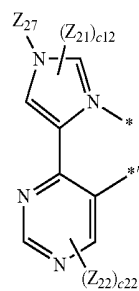
Formula 4-21



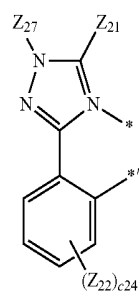
Formula 4-22



Formula 4-23

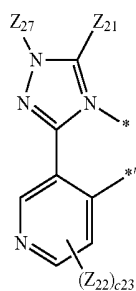


Formula 4-24

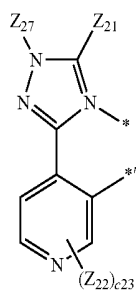


Formula 4-25

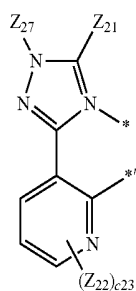
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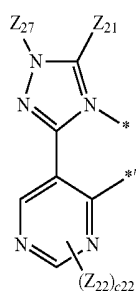
Formula 4-26



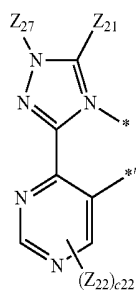
Formula 4-27



Formula 4-28

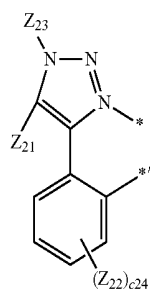


Formula 4-29

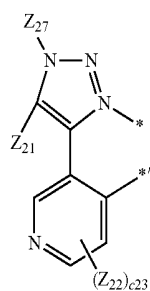


Formula 4-30

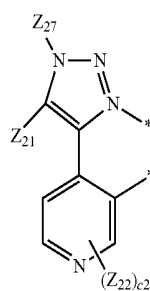
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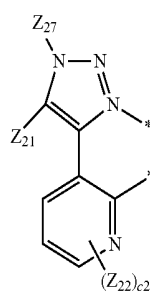
Formula 4-31



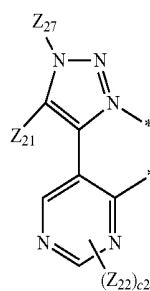
Formula 4-32



Formula 4-33

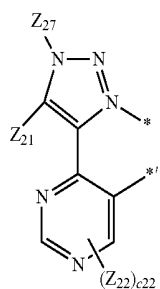


Formula 4-34

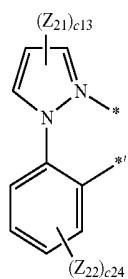


Formula 4-35

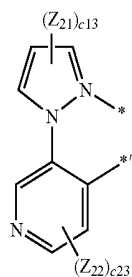
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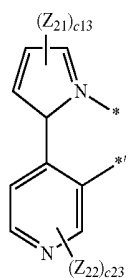
Formula 4-36



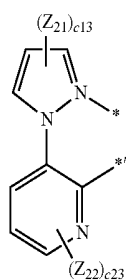
Formula 4-37



Formula 4-38

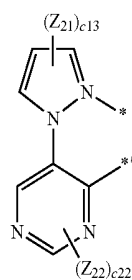


Formula 4-39

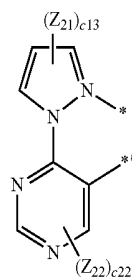


Formula 4-40

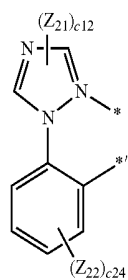
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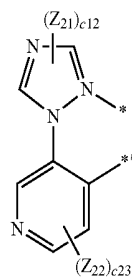
Formula 4-41



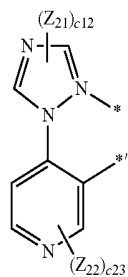
Formula 4-42



Formula 4-43

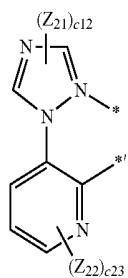


Formula 4-44

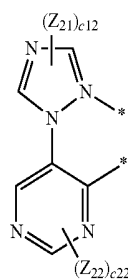


Formula 4-45

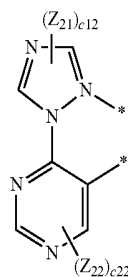
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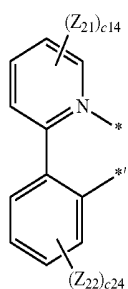
Formula 4-46



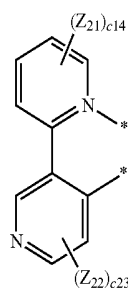
Formula 4-47



Formula 4-48

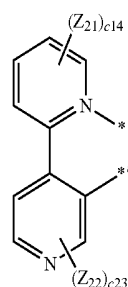


Formula 4-49

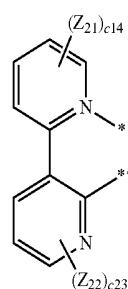


Formula 4-50

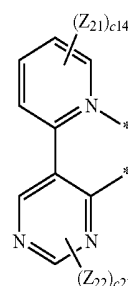
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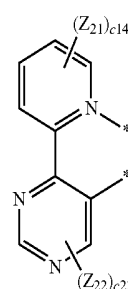
Formula 4-51



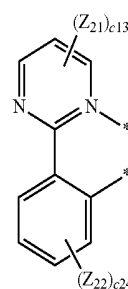
Formula 4-52



Formula 4-53

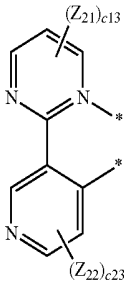


Formula 4-54

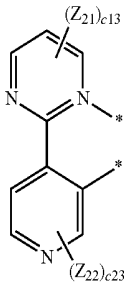


Formula 4-55

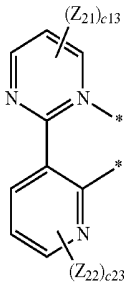
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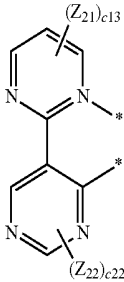
Formula 4-56



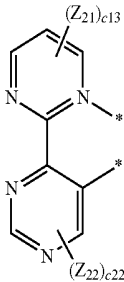
Formula 4-57



Formula 4-58

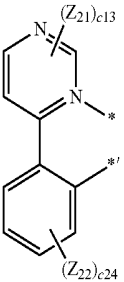


Formula 4-59

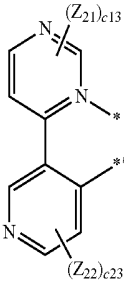


Formula 4-60

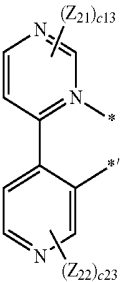
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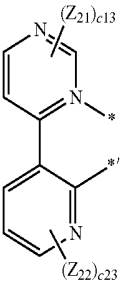
Formula 4-61



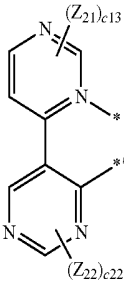
Formula 4-62



Formula 4-63

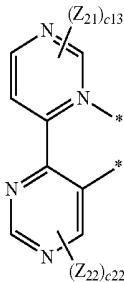


Formula 4-64

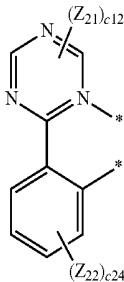


Formula 4-65

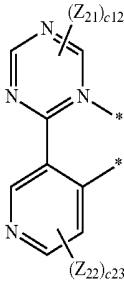
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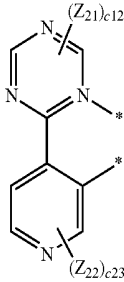
Formula 4-66



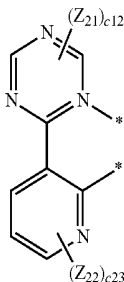
Formula 4-67



Formula 4-68

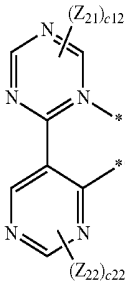


Formula 4-69

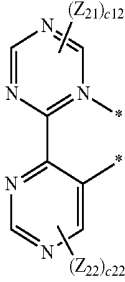


Formula 4-70

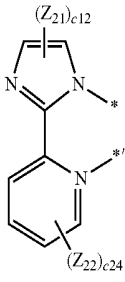
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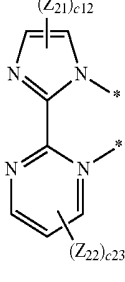
Formula 4-71



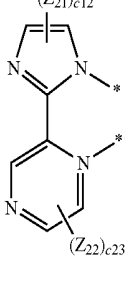
Formula 4-72



Formula 4-73

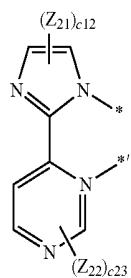


Formula 4-74

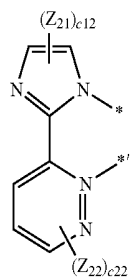


Formula 4-75

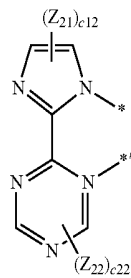
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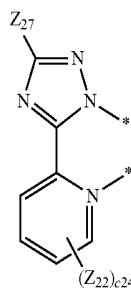
Formula 4-76



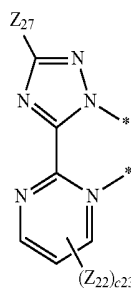
Formula 4-77



Formula 4-78

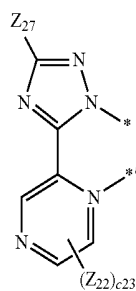


Formula 4-79

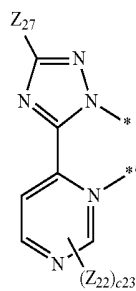


Formula 4-80

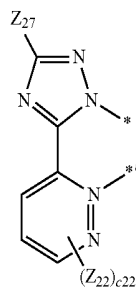
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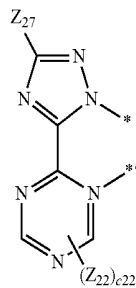
Formula 4-81



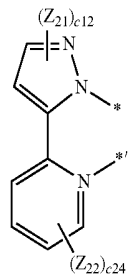
Formula 4-82



Formula 4-83

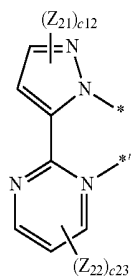


Formula 4-84

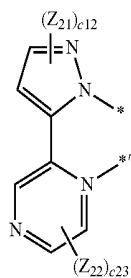


Formula 4-85

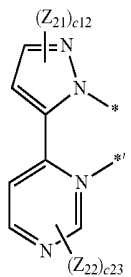
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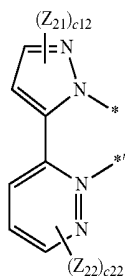
Formula 4-86



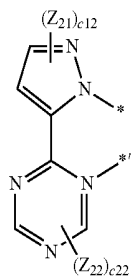
Formula 4-87



Formula 4-88

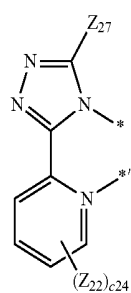


Formula 4-89

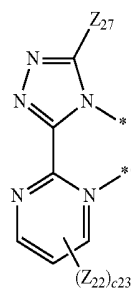


Formula 4-90

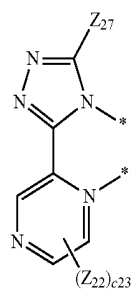
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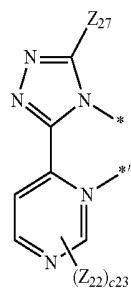
Formula 4-91



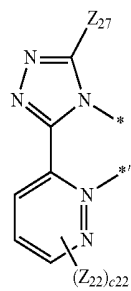
Formula 4-92



Formula 4-93

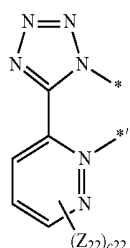
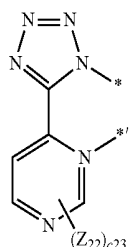
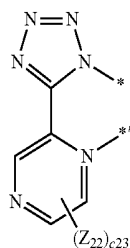
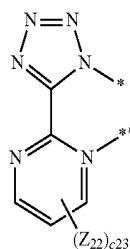
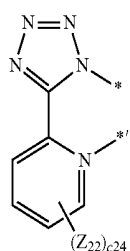
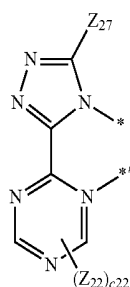


Formula 4-94



Formula 4-95

-continued



Formula 4-96

Formula 4-97

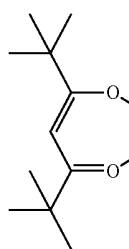
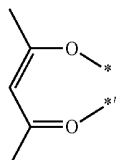
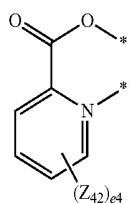
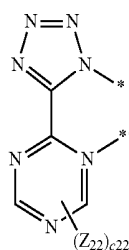
Formula 4-98

Formula 4-99

Formula 4-100

Formula 4-102

-continued



Formula 4-103

Formula 4-104

Formula 4-104

Formula 4-105

[0152] Descriptions for Z_{27} in Formulae 4-1 to 4-104 may be the same as defined in connection with Z_{21} herein.

[0153] In some embodiments, in Formulae 4-1 to 4-104, Z_{21} to Z_{23} and Z_{27} may be each independently selected from

[0154] a hydrogen, —F, a cyano group, a nitro group, —SF₅, a methyl group, an ethyl group, a propyl 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-decanyl group, an isodecanyl group, a sec-decanyl group, a tert-decanyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothioiophenyl group; and

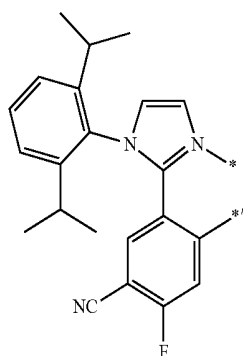
[0155] a methyl group, an ethyl group, a propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an isohexyl group, a sec-hexyl group, a tert-hexyl group, 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-decanyl group, an isodecanyl group, a sec-decanyl group, a tert-decanyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from —F, a cyano group, and a nitro group;

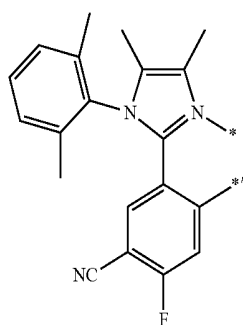
[0156] c12 and c22 may be each independently selected from 1 and 2, c13 and c23 may be each independently selected from 1, 2, and 3, c14 and c24 may be each independently selected from 1, 2, 3, and 4;

[0157] * and *' may each indicate a binding site to M in Formula 1, but is not limited thereto.

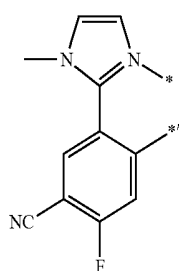
[0158] In some embodiments, in Formula 1, L₁ may be selected from a ligand represented by Formulae 2(1) to 2(10) below, and L₂ may be selected from a ligand represented by Formulae 3-1(1) to 3-1(68) below, but they are not limited thereto:



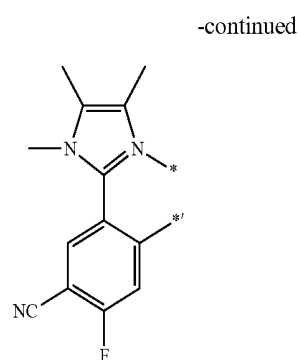
Formula 2(1)



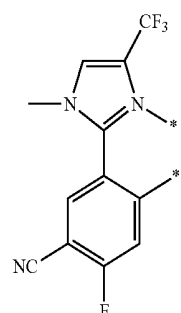
Formula 2(2)



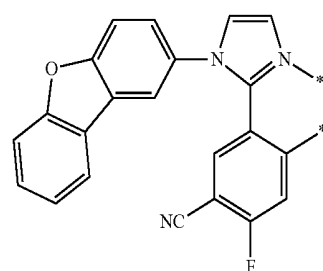
Formula 2(3)



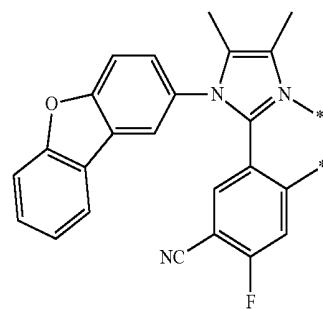
Formula 2(4)



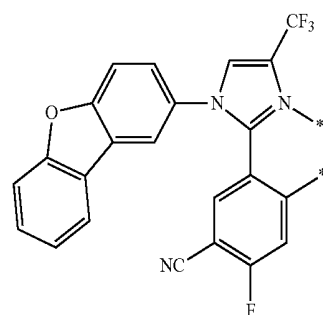
Formula 2(5)



Formula 2(6)

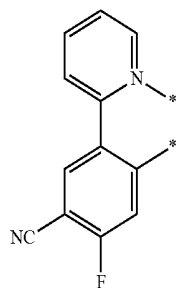


Formula 2(7)

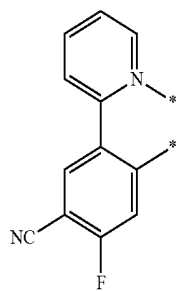


Formula 2(8)

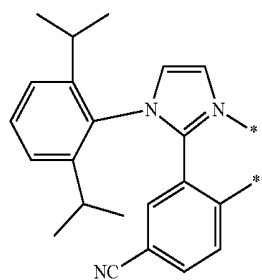
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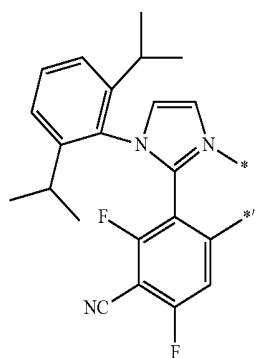
Formula 2(9)



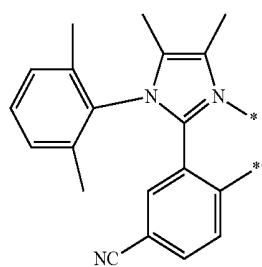
Formula 2(10)



Formula 3-1(1)

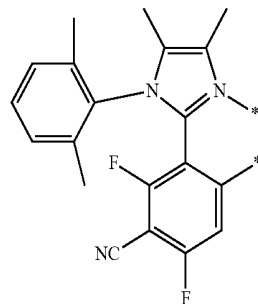


Formula 3-1(2)

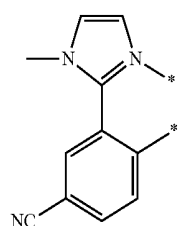


Formula 3-1(3)

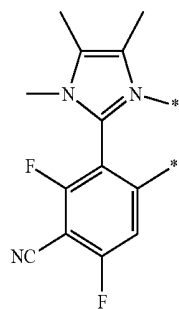
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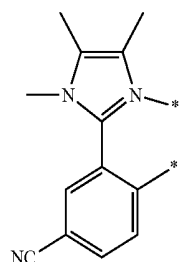
Formula 3-1(4)



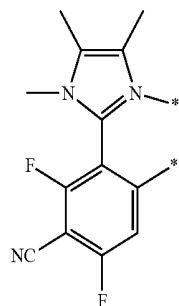
Formula 3-1(5)



Formula 3-1(6)

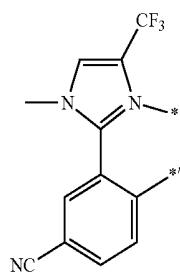


Formula 3-1(7)

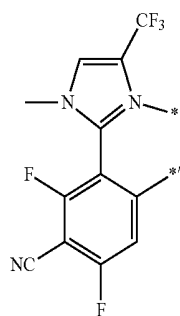


Formula 3-1(8)

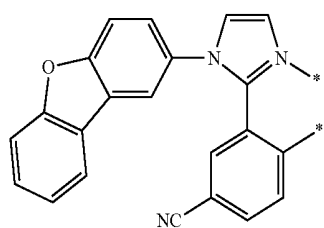
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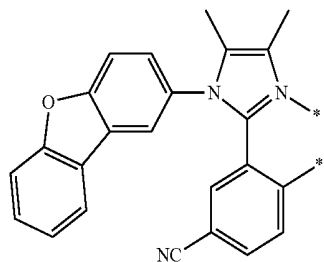
Formula 3-1(9)



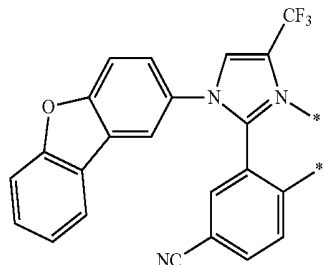
Formula 3-1(10)



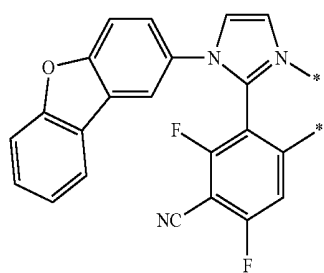
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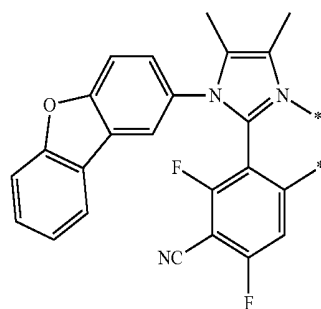


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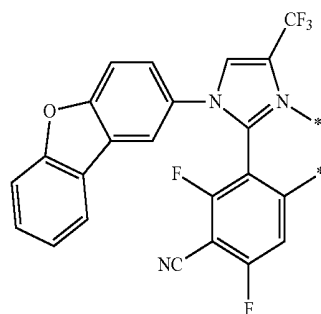


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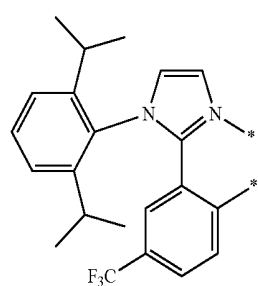
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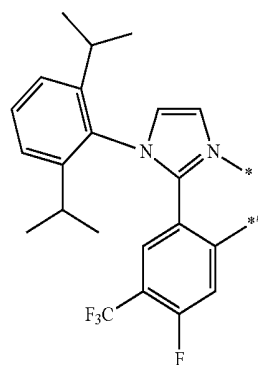
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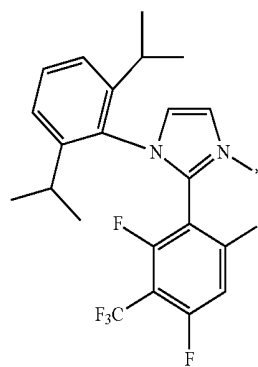
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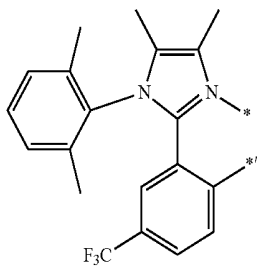


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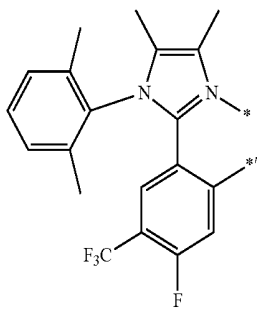


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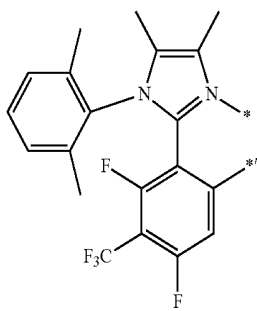
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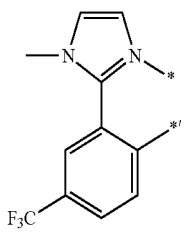
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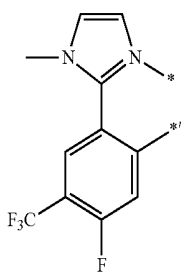
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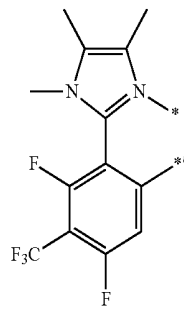


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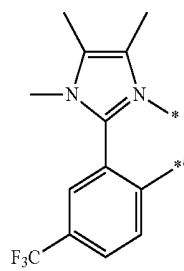


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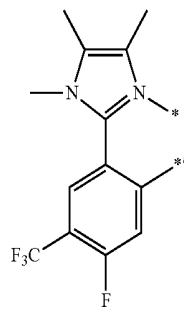
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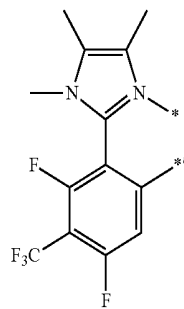
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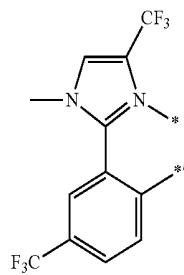
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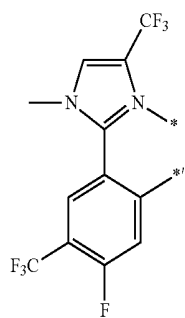


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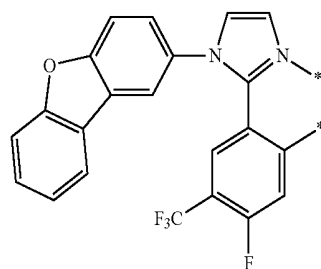
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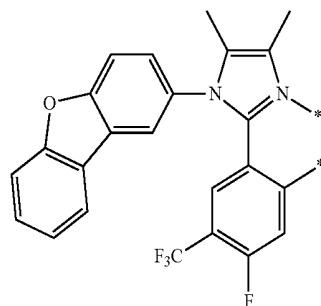
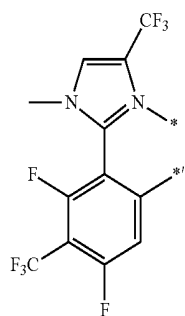
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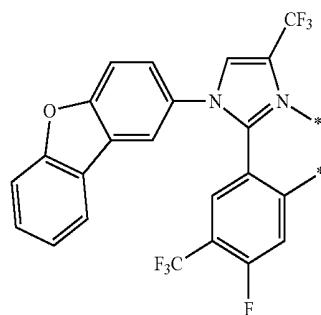
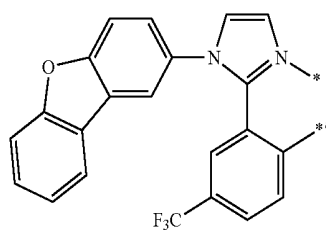
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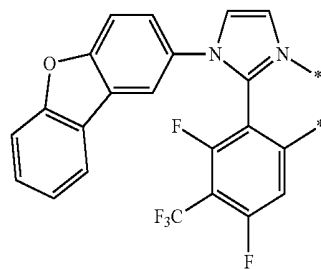
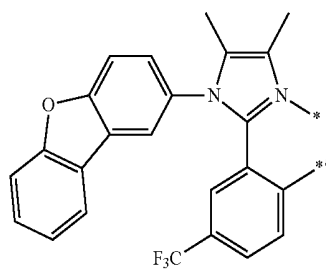
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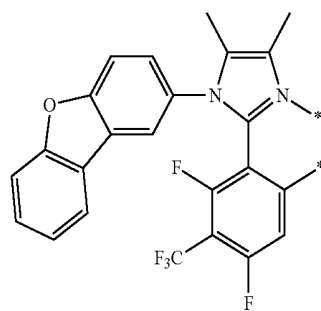
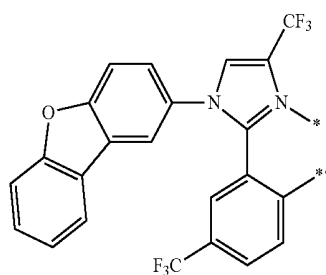
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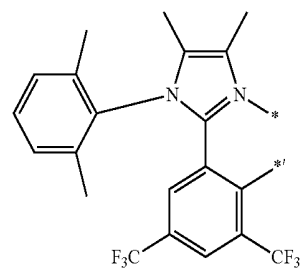
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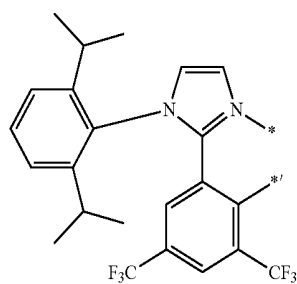


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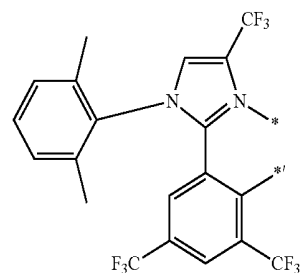
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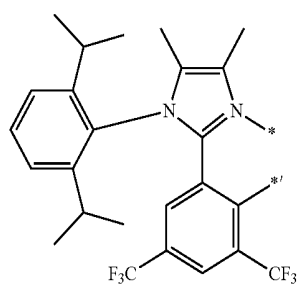
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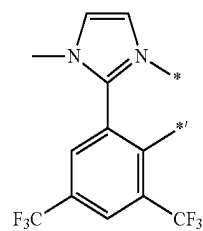
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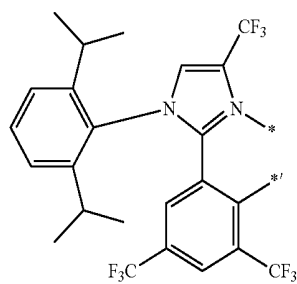
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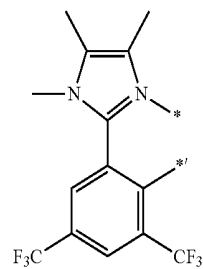
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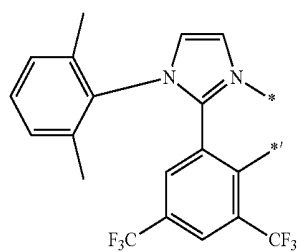
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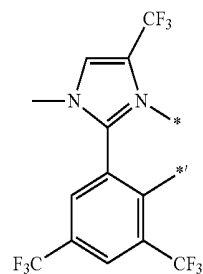
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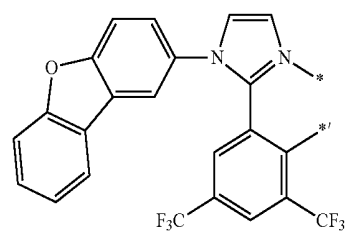
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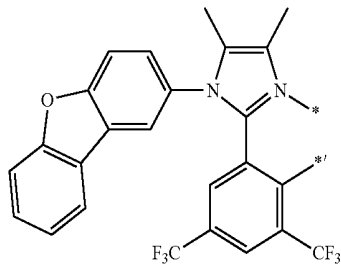


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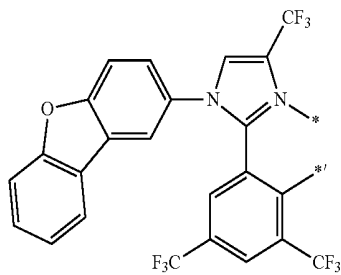


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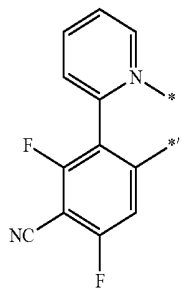
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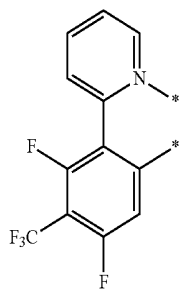
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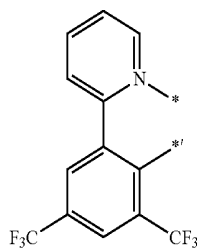
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Formula 3-1(53)

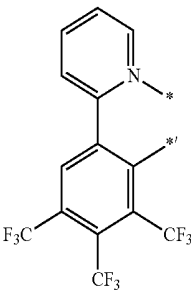


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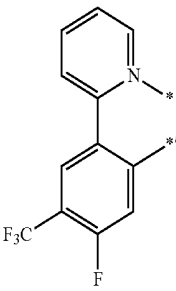


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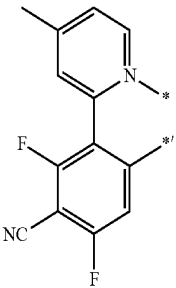
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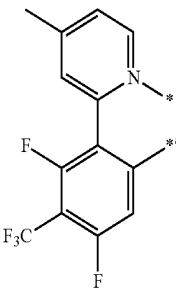
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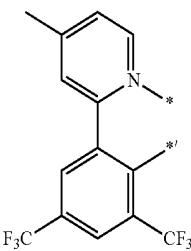
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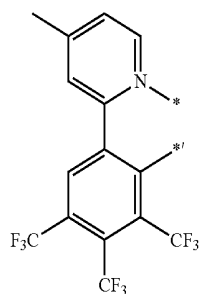


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Formula 3-1(60)

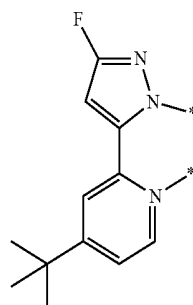
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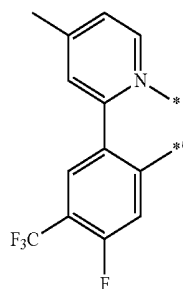
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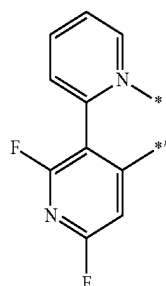
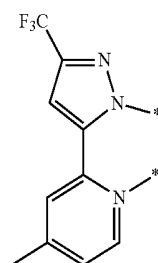


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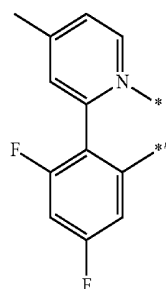
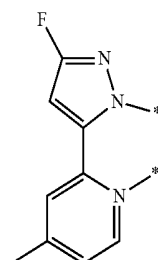
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Formula 3-1(67)

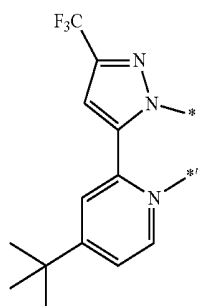


Formula 3-1(64)

Formula 3-1(68)



Formula 3-1(65)



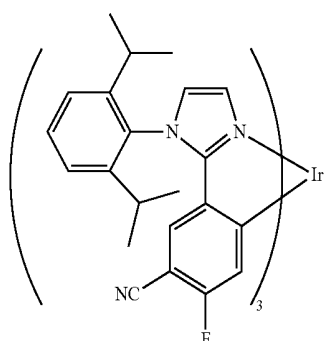
[0159] In Formula 1, n_1 indicates the number of groups L_1 , and n_1 may be an integer selected from 1 to 3. When n_1 is two or more, groups L_1 may be identical or different.

[0160] In Formula 1, n_2 may be an integer selected from 0 to 4. When n_2 is 2 or more, groups L_2 may be identical or different. For example, n_2 may be 0, 1 or 2, but is not limited thereto.

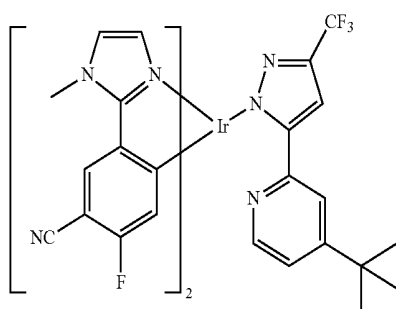
[0161] In some embodiments, in Formula 1, $n_1=3$, and $n_2=0$; $n_1=2$, and $n_2=1$; or $n_1=1$, and $n_2=2$; but is not limited thereto.

[0162] In some embodiments, in Formula 1, n_1 may be 3, and all three groups L_1 may all be identical to each other; and n_2 may be 2, and both groups L_1 may be identical to each other.

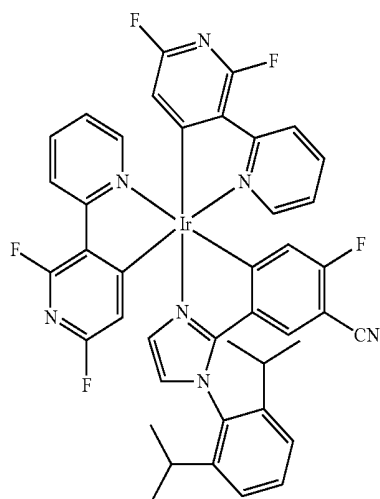
[0163] The organometallic compound represented by Formula 1 may be selected from Compounds 1 to 4 below.



Compound 1

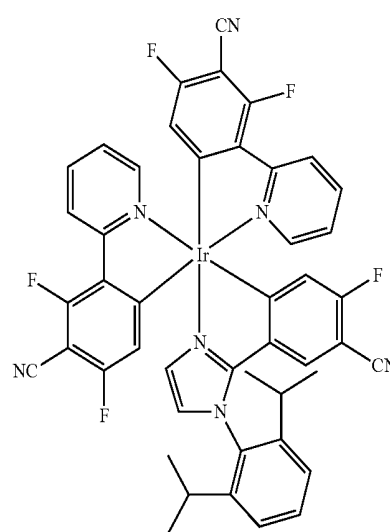


Compound 2



Compound 3

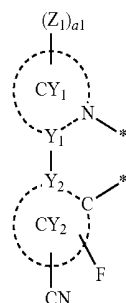
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Compound 4

[0164] The organometallic compound represented by Formula 1 includes at least one group L_1 represented by Formula 2, and Formula 2 includes one cyano group and one $-F$, as substituents of CY_2 . $-F$ has a very high reactivity, and thus when a compound including $-F$ as a substituent, is exposed to relatively high temperature (for example, vapor deposition temperature when the compound is vapor deposited on a predetermined substrate), $-F$ may be separated from the compound. Accordingly, the organic light-emitting device using the compound may have a decreased lifespan. However, in Formula 2, CY_2 has one cyano group and one $-F$. Therefore, the organometallic compound has the least number of $-F$ in Formula 2, and such the organometallic compound may ensure thermal stability, a high color coordination and highest occupied molecular orbital (HOMO) level (for example, a color coordination and a HOMO level that is suitable for use in emission of deep blue light) by using $-CN$.

Formula 2



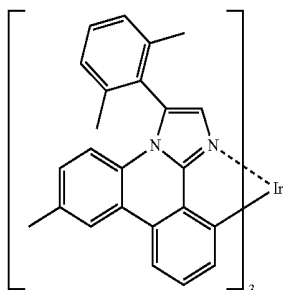
[0165] In addition, the organometallic compound comprising a ligand(s) represented by Formula 2 has a high dispersion property. Accordingly, when an organic light-emitting device has the organometallic compound represented by Formula 1 as a dopant, efficiency of the organic light-emitting device may be improved.

[0166] For example, the organometallic compound represented by Formula 1 enables emission of deep blue light which has a maximum emission wavelength of about 435 nanometers (nm) to about 500 nm, the x color coordinate of

about 0.14 to about 0.20 (for example, in a range of about 0.14 to about 0.18) and the y color coordinate of about 0.10 to about 0.30 (for example, in a range of about 0.15 to about 0.25). The highest occupied molecular orbital (HOMO), lowest unoccupied molecular orbital (LUMO), and triplet (T₁) energy level of each of Compounds 1 and A were evaluated according to DFT method using Gaussian program (structural optimization was performed at B3LYP, 6-31G(d,p) levels), and the evaluation results are shown in Table 1 below.

TABLE 1

Compound No.	HOMO (eV)	LUMO (eV)	T ₁ energy level (eV)
1	-5.28	-1.18	2.91
A	-4.56	-0.76	2.85



Compound A

[0167] Referring to Table 1, it is confirmed that Compound 1 has a HOMO, LUMO, and T₁ energy level that are suitable for use as a material for an organic light-emitting device in comparison to Compound A. Accordingly, the organometallic compound represented by Formula 1 has electric characteristics that are suitable for use as a material for an organic light-emitting device.

[0168] Synthesis methods of the organometallic compound represented by Formula 1 may be understood by one of ordinary skill in the art by referring to Synthesis Examples provided below.

[0169] The organometallic compound represented by Formula 1 is suitable for use in an organic layer of an organic light-emitting device, for example, for use as a dopant in an emission layer of the organic layer. Thus, another aspect provides an organic light-emitting device that includes: a first electrode; a second electrode; and an organic layer disposed between the first electrode and the second electrode, wherein the organic layer includes an emission layer and at least one organometallic compound represented by Formula 1.

[0170] The organic light-emitting device may have, due to the inclusion of an organic layer including the organometallic compound represented by Formula 1, low driving voltage, high efficiency, high brightness, and long lifespan. In addition, the organic light-emitting device using the organometallic compound represented by Formula 1 enables emission of deep blue light which has a maximum emission wavelength of about 435 nm to about 500 nm, the x color coordinate of about 0.14 to about 0.20 (for example, in a range of about 0.14 to about 0.18), and the y color coordinate of about 0.10 to about 0.30 (for example, in a range of about 0.15 to about 0.25).

[0171] The organometallic compound of Formula 1 may be used between a pair of electrodes of an organic light-emitting device. For example, the organometallic compound repre-

sented 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, an amount of the organometallic compound represented by Formula 1 is smaller than an amount of the host).

[0172] The expression “(an organic layer) includes at least one organometallic compound” as used herein may include an embodiment in which “(an organic layer) includes identical organometallic compounds of Formula 1 and an embodiment in which (an organic layer) includes two or more different organometallic compounds of Formula 1.

[0173] For example, the organic layer may include, as the organometallic compound, only Compound 1. In this regard, Compound 1 may be situated 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 situated in an identical layer (for example, both Compound 1 and Compound 2 all may be situated in an emission layer).

[0174] 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, or the second electrode may be an anode, which is a hole injection electrode.

[0175] For example, the first electrode may be an anode, and the second electrode may be a cathode, and the organic layer may include: i) a hole transport region that is disposed between the first electrode and the emission layer, wherein the hole transporting region may include at least one of a hole injection layer, a hole transport layer, and an electron blocking layer, and ii) an electron transport region that is disposed between the emission layer and the second electrode, wherein the electron transporting region may include at least one selected from a hole blocking layer, an electron transport layer, and an electron injection layer.

[0176] The term “organic layer” as used herein refers to a single layer and/or a plurality of layers disposed between the first electrode and the second electrode of an organic light-emitting device. The “organic layer” may include, in addition to an organic compound, an organometallic complex including metal.

[0177] 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-emitting device 10 includes a first electrode 11, an organic layer 15, and a second electrode 19, which are sequentially stacked.

[0178] In FIG. 1, a substrate (not shown) may be additionally disposed under the first electrode 11 or above the second electrode 19. For use 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-proofness.

[0179] The first electrode 11 may be formed by depositing or sputtering a material for forming the first electrode 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 an indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO₂), or zinc oxide (ZnO). In some embodiments, the material for the first electrode **11** may be metal, such as magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), or magnesium-silver (Mg—Ag).

[0180] 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 **11** is not limited thereto.

[0181] An organic layer **15** is disposed on the first electrode **11**.

[0182] The organic layer **15** may include a hole transport region, an emission layer, and an electron transport region.

[0183] The hole transport region may be disposed between the first electrode **11** and the emission layer.

[0184] The hole transport region may include at least one of a hole injection layer, a hole transport layer, an electron blocking layer, and a buffer layer.

[0185] The hole transport region may include only either a hole injection layer or a hole transport layer. According to another embodiment, 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**.

[0186] When the hole transport region includes a hole injection layer (HIL), the hole injection layer may be formed on the first electrode **11** by using any one of various methods, for example, vacuum deposition, spin coating, casting, or Langmuir-Blodgett (LB) deposition.

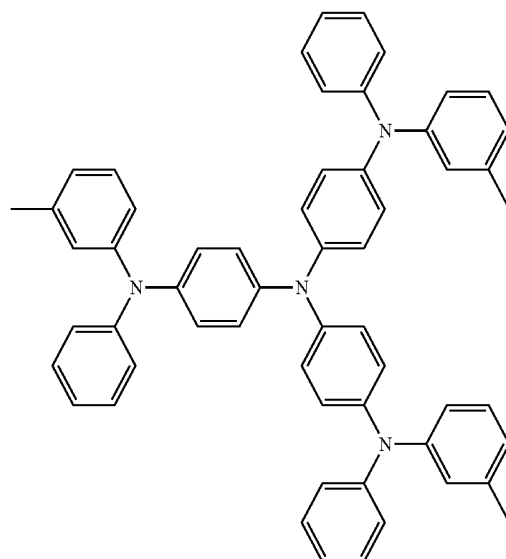
[0187] When a hole injection layer is formed by vacuum deposition, the deposition conditions may vary according to a material that is used to form the hole injection layer, and the structure and thermal characteristics of the hole injection layer. For example, the deposition conditions may include a 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 (Å/sec). However, the deposition conditions are not limited thereto.

[0188] When the hole injection layer is formed by 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.

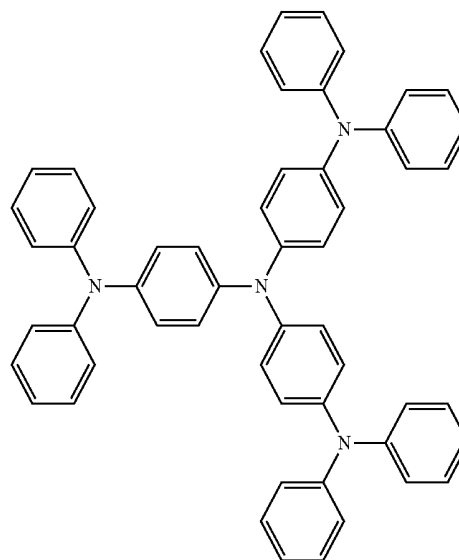
[0189] Conditions for a hole transport layer and an electron blocking layer may be understood by referring to conditions for forming the hole injection layer.

[0190] 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, HMTDP, 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:

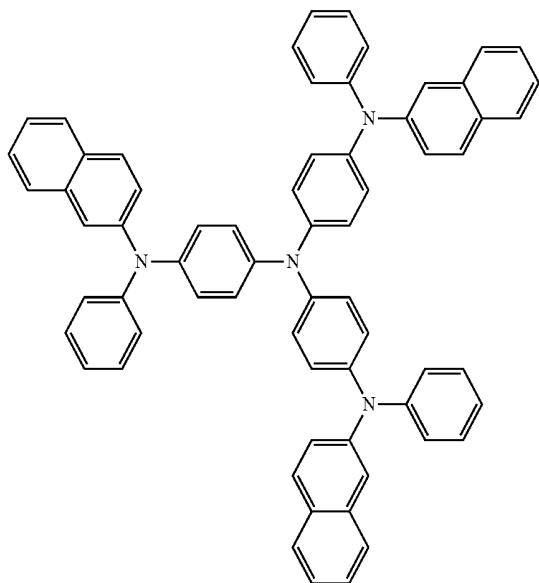


m-MTDATA



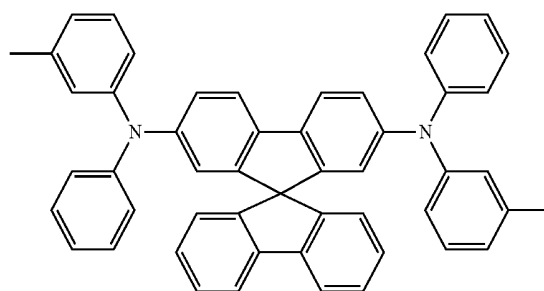
TDATA

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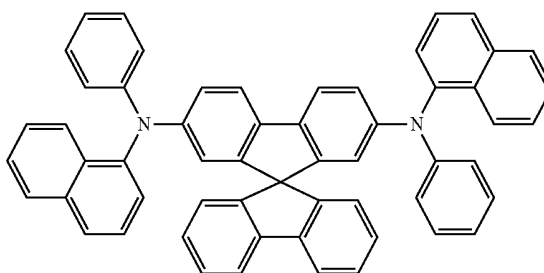


2-TNATA

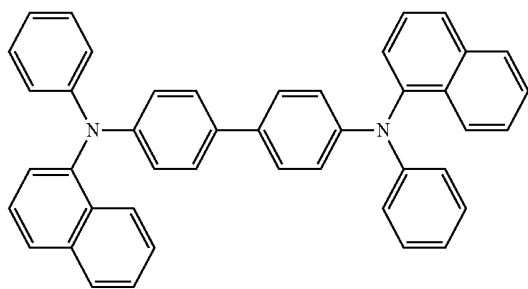
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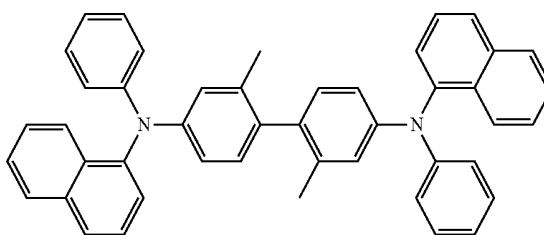
Spiro-TPD



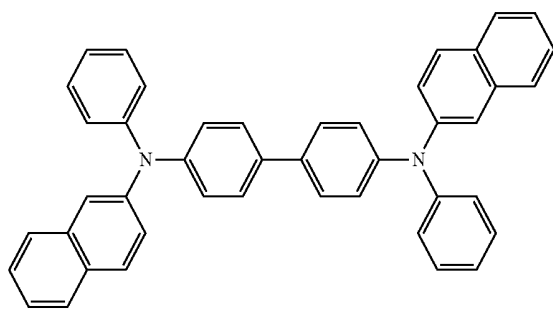
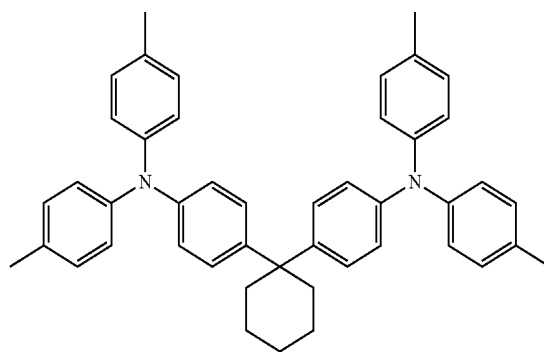
Spiro-NPB



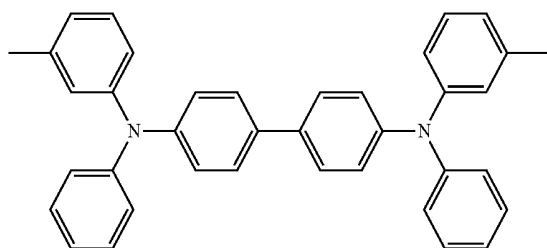
NPB



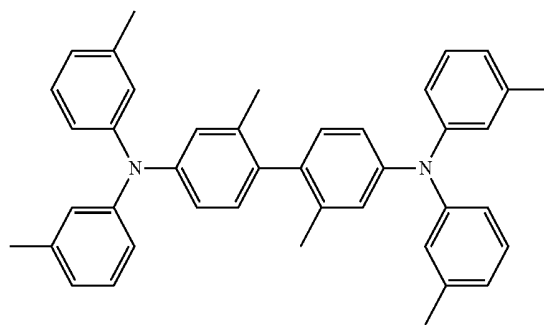
methylated NPB

 β -NPB

TAPC



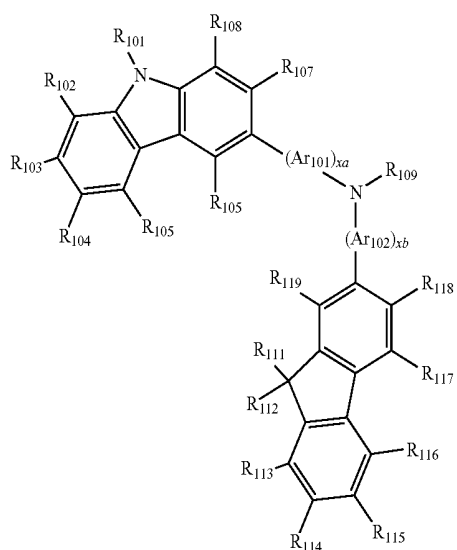
TPD



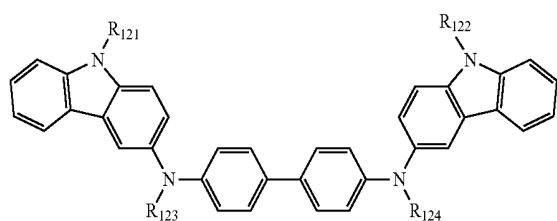
HMTDP

-continued

Formula 201



Formula 202



[0191] wherein in Formula 201, Ar₁₀₁ and Ar₁₀₂ may be each independently selected from

[0192] 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 chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, and a pentacenylene group; and

[0193] 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 chrysenylene group, a naphthacenylenylene group, a picenylene group, a perylenylene group, and a pentacenylene group, each substituted with at least one of 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, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a

C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

[10194] x_a and x_b in Formula 201 may be each independently an integer selected from 0 to 5, or 0, 1 or 2. For example, x_a may be 1 and x_b may be 0, but x_a and x_b are not limited thereto.

[0195] R₁₀₁ to R₁₀₈, R₁₁₁ to R₁₁₉, and R₁₂₁ to R₁₂₄ in Formulae 201 and 202 may be each independently selected from

[0196] a hydrogen, 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, a phosphoric acid group or a salt thereof, a C₁-C₁₀ 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 C₁-C₁₀ alkoxy group (for example, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, and so on);

[0197] a C₁-C₁₀ alkyl group and a C₁-C₁₀ 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;

[0198] a phenyl group, a naphthyl group, an anthracenyl group, a fluorenyl group, and a pyrenyl group; and

[0199] a phenyl group, a naphthyl group, an anthracenyl 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 C₁-C₁₀ alkyl group, and a C₁-C₁₀ alkoxy group, but they are not limited thereto.

[0200] In Formula 201, R₁₀₉ may be selected from

[0201] a phenyl group, a naphthyl group, an anthracenyl group, and a pyridinyl group; and

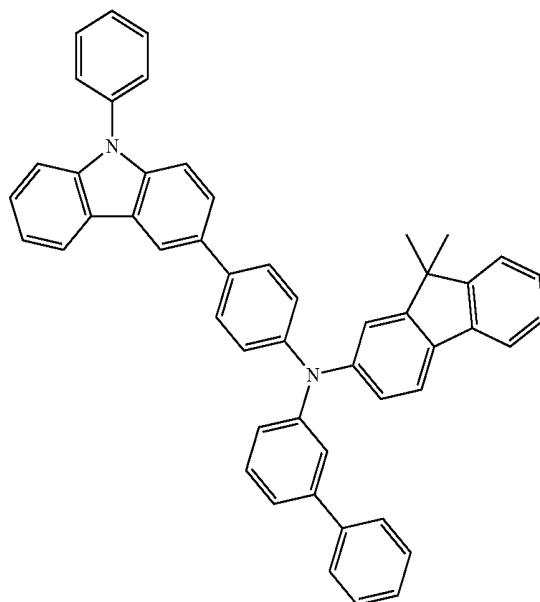
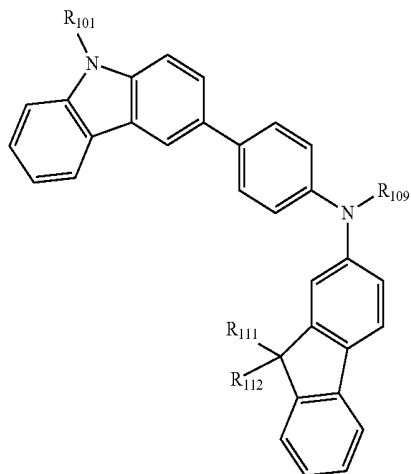
[0202] a phenyl group, a naphthyl group, an anthracenyl group, and a pyridinyl group, each substituted with at least one selected from a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, and a pyridinyl group.

[0203] In some embodiments, the compound represented by Formula 201 may be represented by Formula 201A below, but is not limited thereto:

-continued

Formula 201A

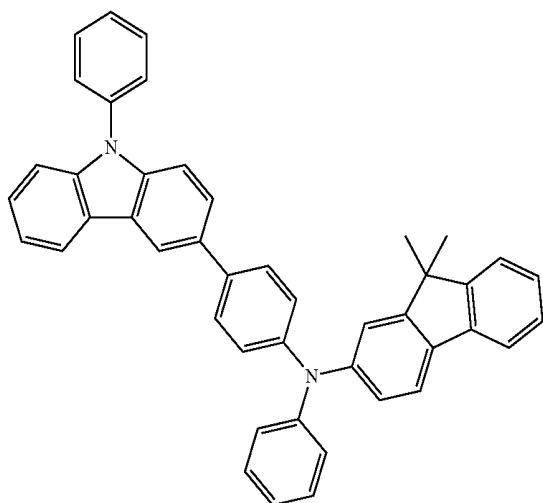
HT2



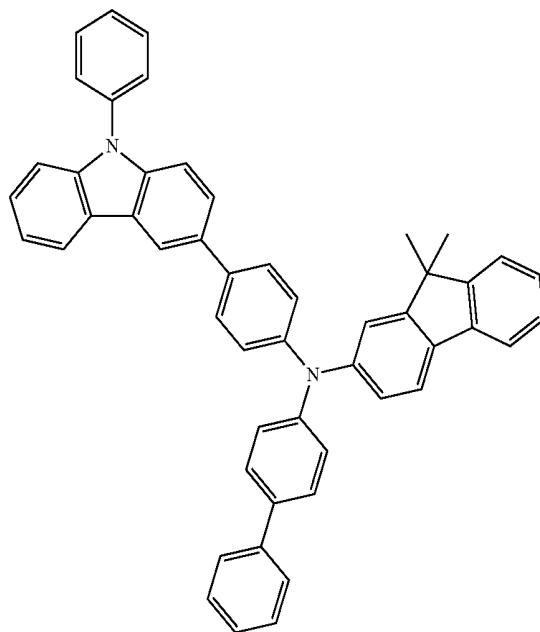
[0204] R_{101} , R_{111} , R_{112} , and R_{109} in Formula 201A may be understood by referring to the description provided herein.

[0205] 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.

HT3

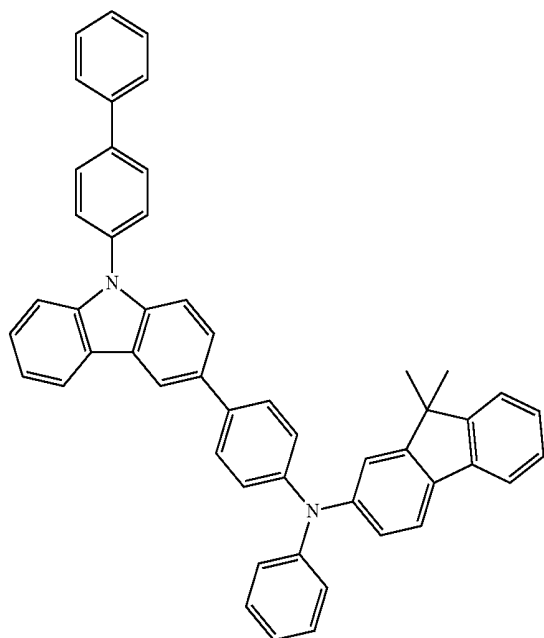


HT1



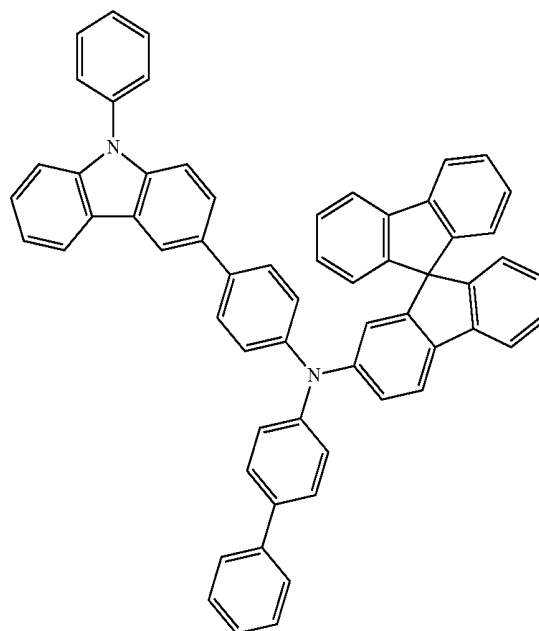
-continued

HT4

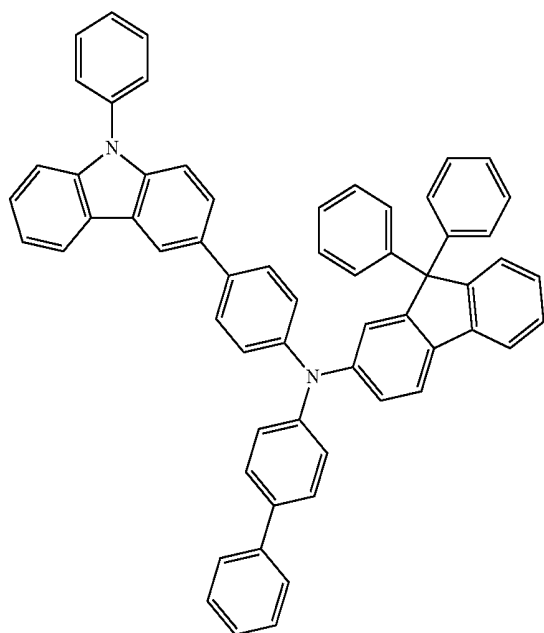


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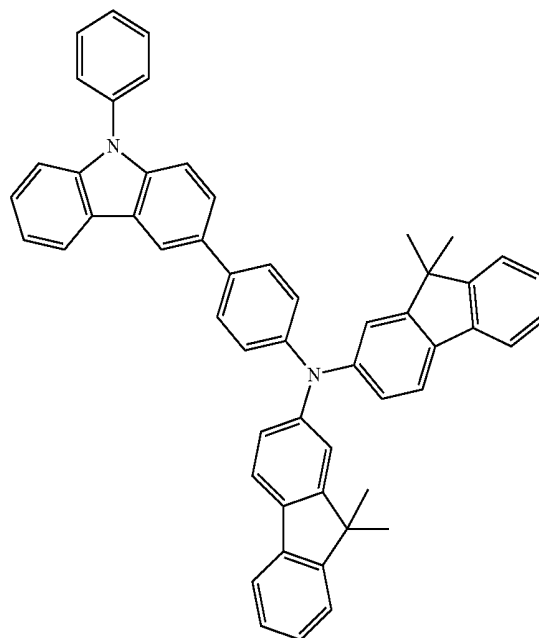
HT6



HT5

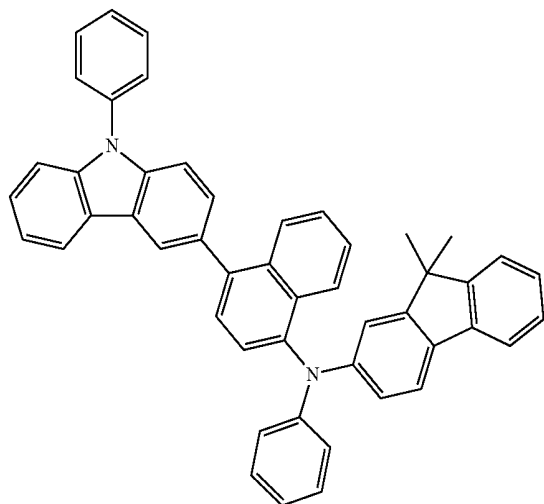


HT7



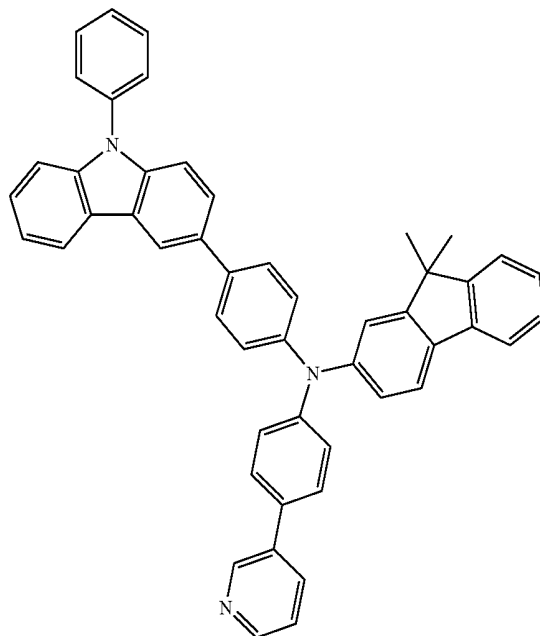
-continued

HT8

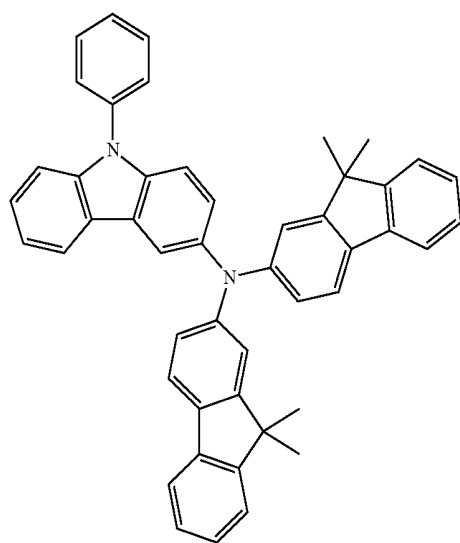


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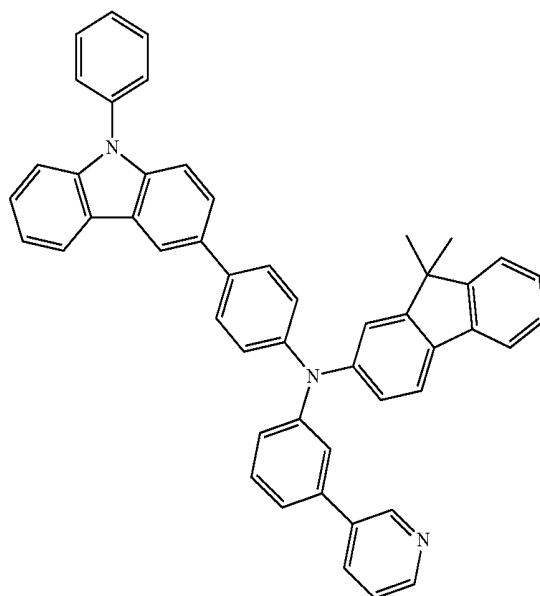
HT10



HT9

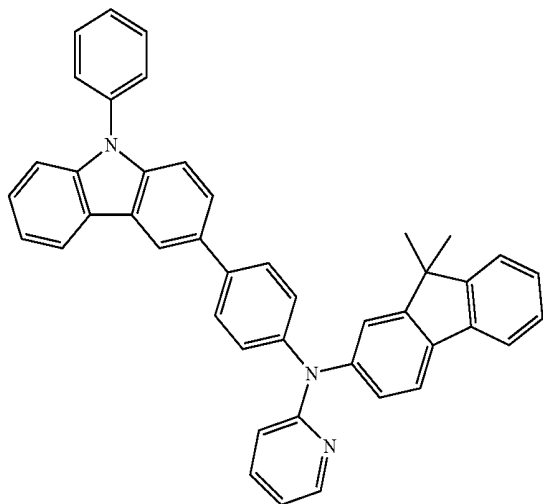


HT11



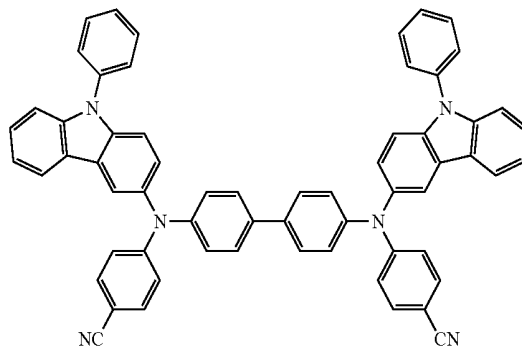
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HT12

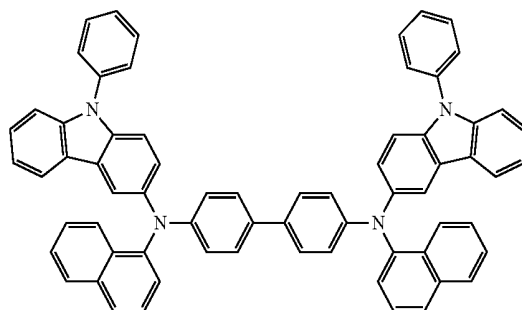


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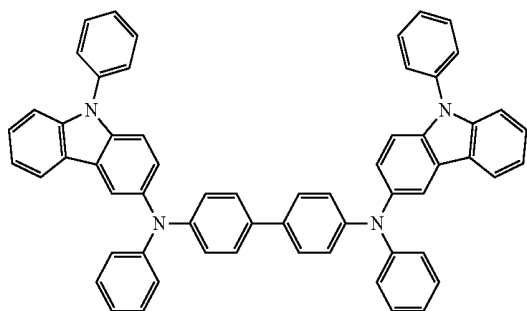
HT16



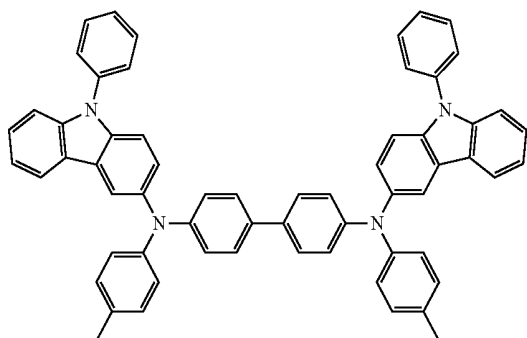
HT17



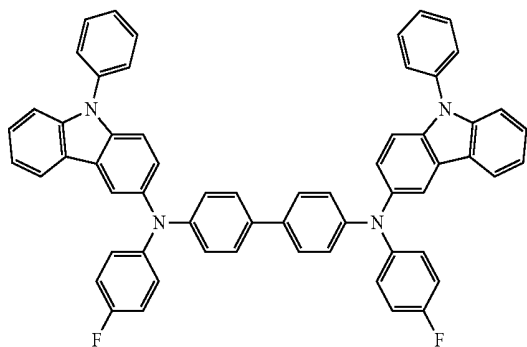
HT13



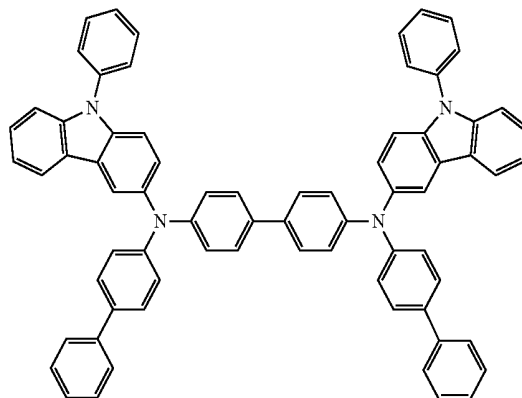
HT14



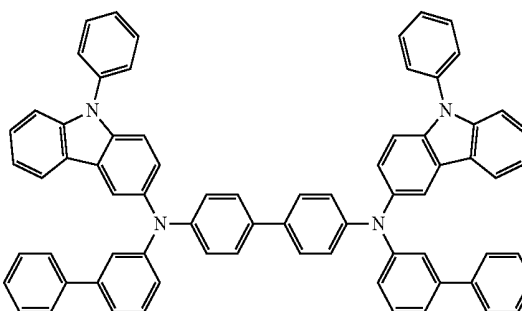
HT15



HT18

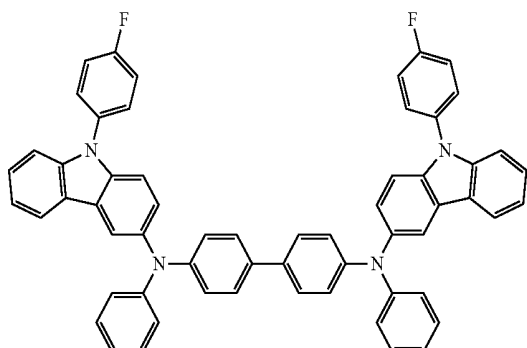


HT19



-continued

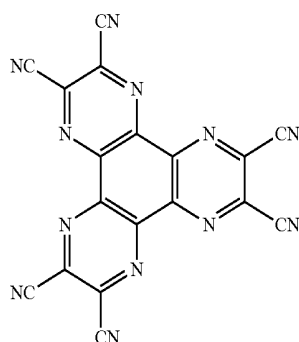
HT20



[0206] 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. When the hole transport region includes both a hole injection layer and a hole transport layer, a thickness of the hole injection layer may be in a range of about 100 Å to about 10,000 Å, for example, about 100 Å to about 1,000 Å, and a thickness of the hole transport layer may be in a range of about 50 Å to about 2,000 Å, for example about 100 Å to about 1,500 Å. When the thicknesses of the hole transport region, the hole injection layer, and the hole transport layer are within these ranges, satisfactory hole transporting characteristics may be obtained without a substantial increase in driving voltage.

[0207] 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.

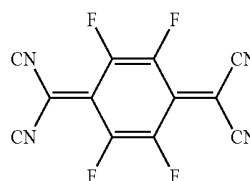
[0208] The charge-generation material may be, for example, a p-dopant. The p-dopant may be one of a quinone derivative, a metal oxide, and a cyano group-containing compound, but is not limited thereto. Non-limiting examples of the p-dopant are a quinone derivative, such as tetracyanoquinonodimethane (TCNQ) or 2,3,5,6-tetrafluoro-tetracyano-1,4-benzoquinonodimethane (F4-TCNQ); a metal oxide, such as a tungsten oxide or a molybdenum oxide; and a cyano group-containing compound, such as Compound 200 (HAT-CN) below, but are not limited thereto.



Compound 200

-continued

F4-TCNQ



[0209] The hole transport region may include a buffer layer.

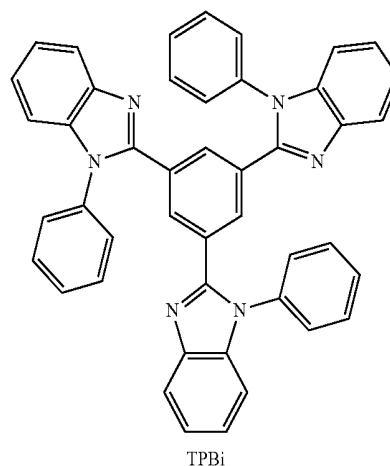
[0210] Also, the buffer layer may compensate for an optical resonance distance according to a wavelength of light emitted from the emission layer, and thus, efficiency of a formed organic light-emitting device may be improved.

[0211] Then, an emission layer (EML) 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.

[0212] When the hole transport region includes an electron blocking layer, a material that is used to form the electron blocking layer may be selected from the material used to form a hole transport region and host materials described herein, but is not limited thereto. For example, when the hole transport region includes an electron blocking layer, mCP described herein may be used to form the electron blocking layer.

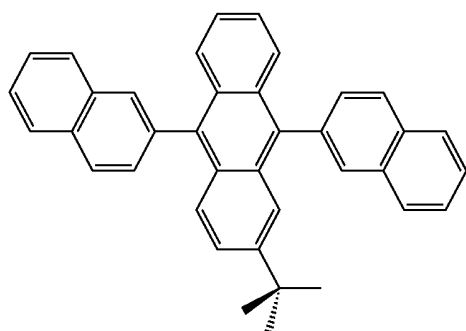
[0213] The emission layer may include a host and a dopant, and the dopant may include the organometallic compound represented by Formula 1.

[0214] The host may include at least one selected from TPBi, TBADN, ADN (also known as "DNA"), CBP, CDBP, TCP, mCP, Compound H50, and Compound H51:

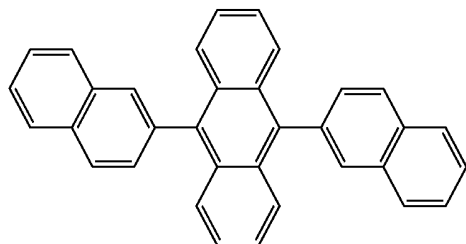


TPBi

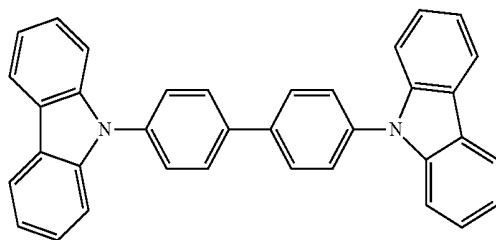
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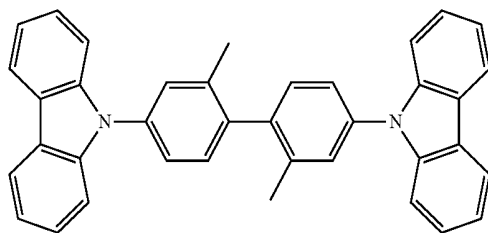
TBADN



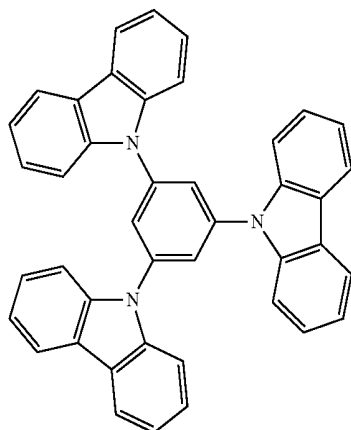
ADN



CBP

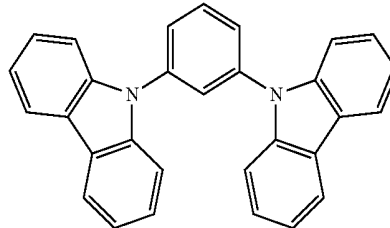


CDBP



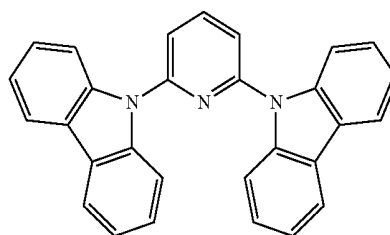
TCP

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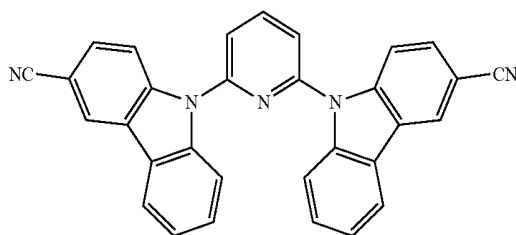


mCP

Compound H50

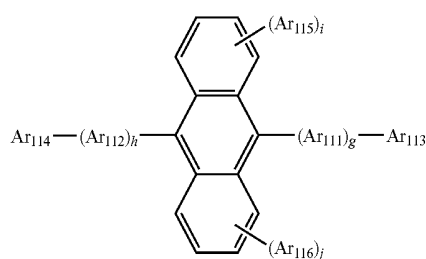


Compound H51



[0215] Alternatively, the host may further include a compound represented by Formula 301 below:

Formula 301



[0216] Ar_{111} and Ar_{112} in Formula 301 may be each independently selected from

[0217] a phenylene group, a naphthylene group, a phenanthrenylene group and a pyrenylene group; and

[0218] 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;

[0219] Ar_{113} and Ar_{116} in Formula 301 may be each independently selected from

[0220] a C_1 - C_{10} alkyl group, a phenyl group, a naphthyl group, a phenanthrenyl group and a pyrenyl group; and

[0221] 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.

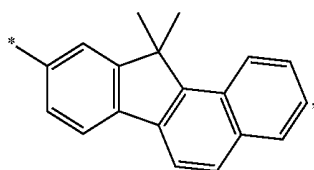
[0222] g, h, l, and j in Formula 301 may be each independently an integer selected from 0 to 4, for example, an integer selected from 0, 1, or 2.

[0223] Ar_{113} and Ar_{116} in Formula 301 may be each independently selected from

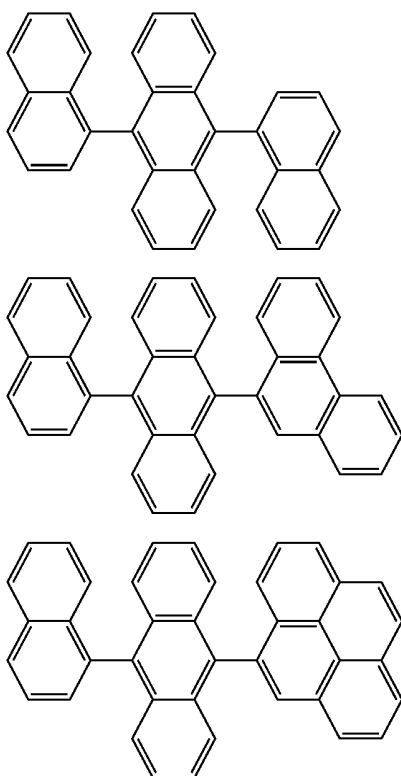
[0224] a C_1 - C_{10} alkyl group substituted with at least one selected from a phenyl group, a naphthyl group, and an anthracenyl group;

[0225] a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, and a fluorenyl group;

[0226] 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 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 phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, and a fluorenyl group; and

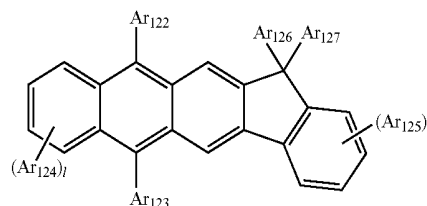


but they are not limited thereto.



[0227] In some embodiments, the host may include a compound represented by Formula 302 below:

Formula 302



[0228] Descriptions for Ar_{122} to Ar_{125} in Formula 302 may be the same as explained in connection with Ar_m in Formula 301.

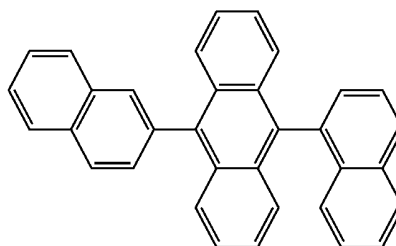
[0229] Ar_{126} and Ar_{127} in Formula 302 may be each independently a C_1 - C_{10} alkyl group (for example, a methyl group, an ethyl group, or a propyl group).

[0230] k and l in Formula 302 may be each independently an integer selected from 0 to 4. For example, k and l may be 0, 1, or 2.

[0231] 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.

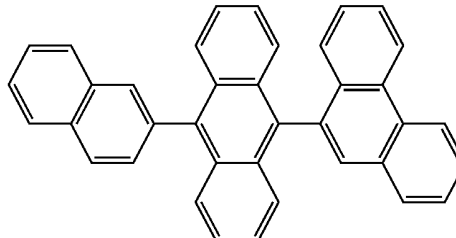
H1

H2



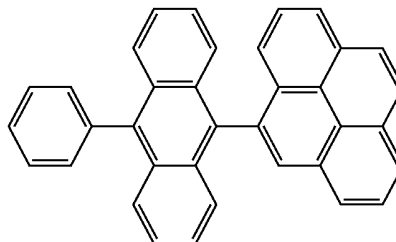
H3

H4

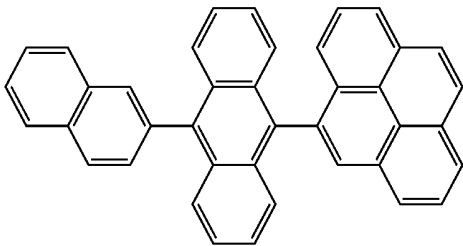


H5

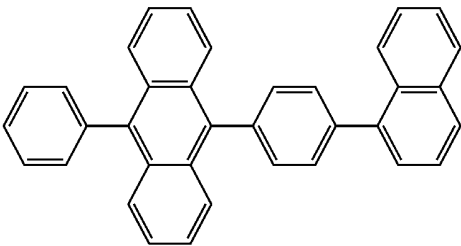
H6



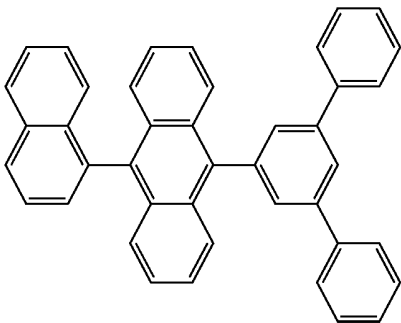
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H7



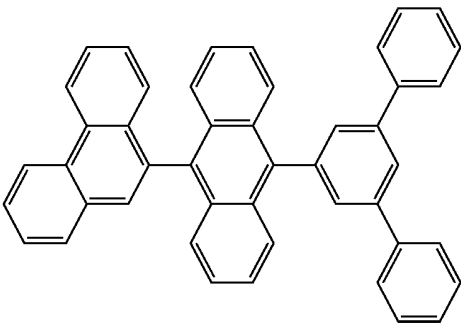
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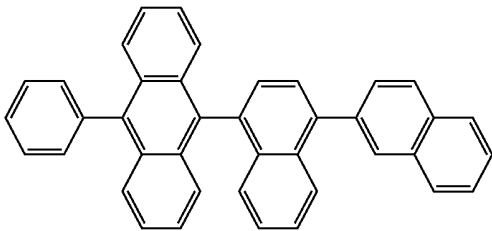
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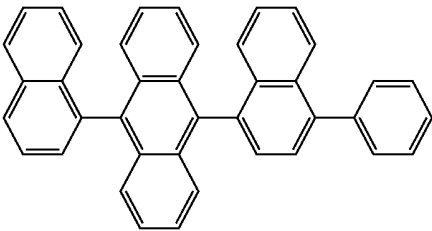
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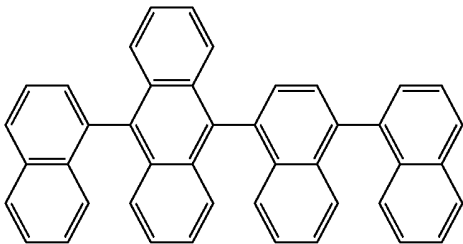
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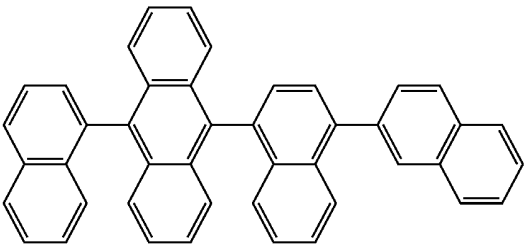
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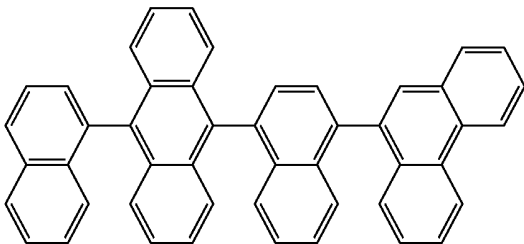
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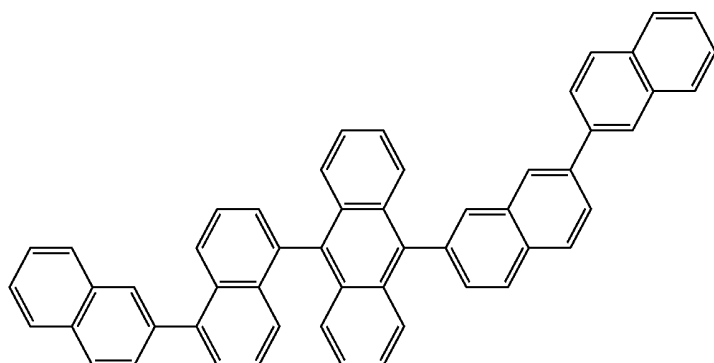
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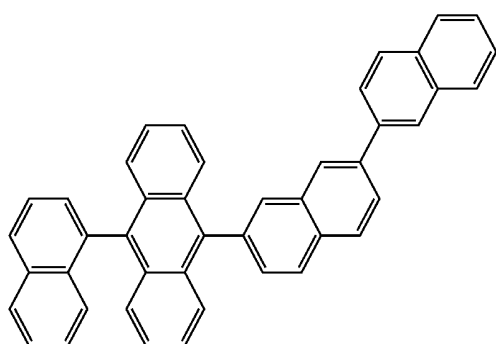
H15



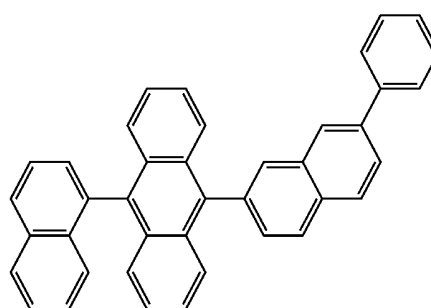
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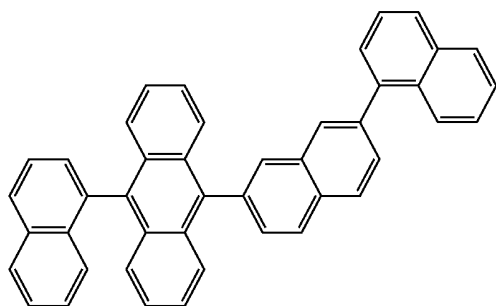
H16



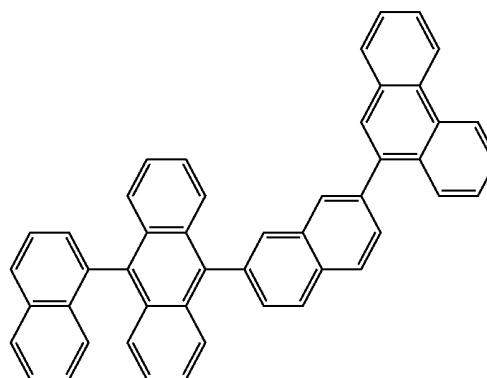
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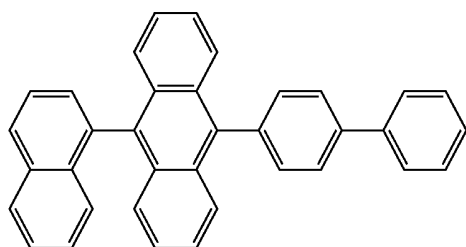
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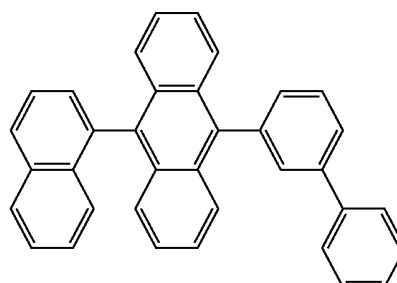
H19



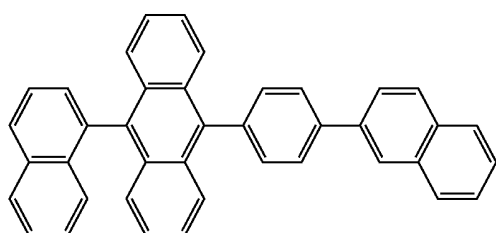
H20



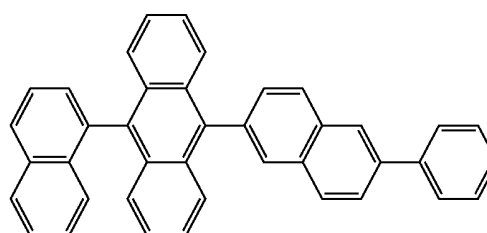
H21



H22



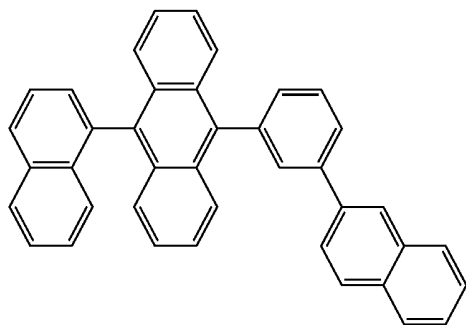
H23



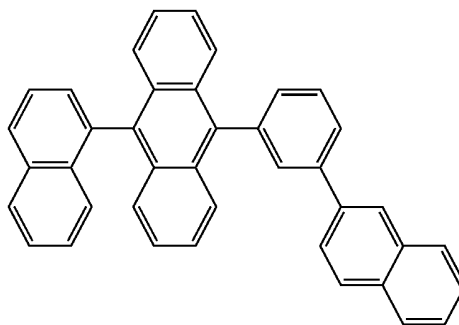
H24

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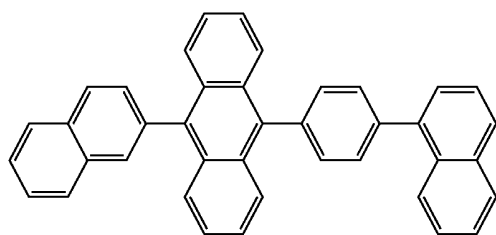
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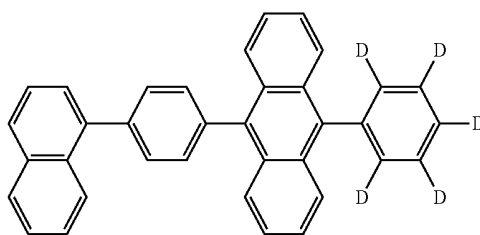
H26



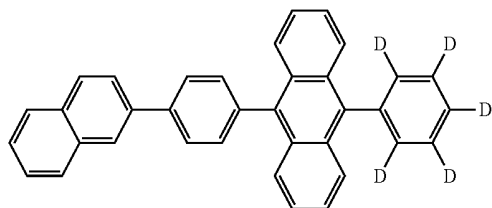
H27



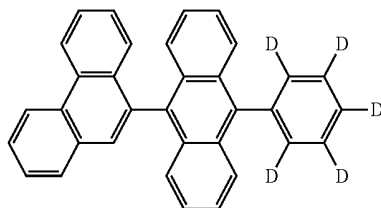
H28



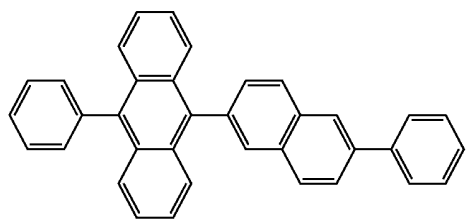
H29



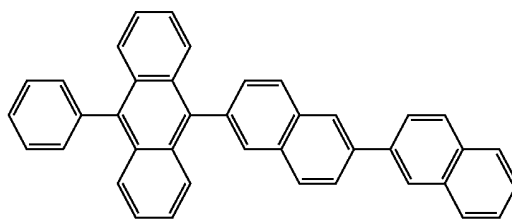
H30



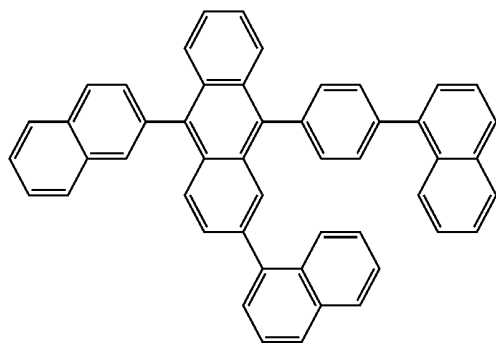
H31



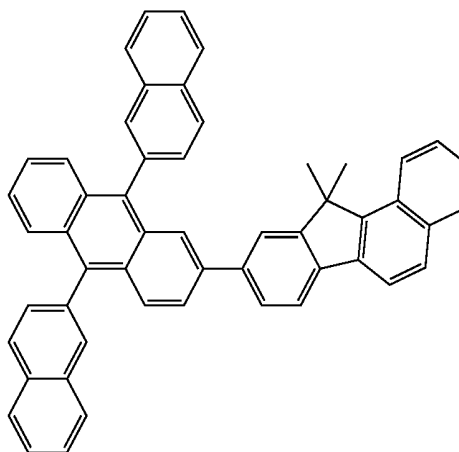
H32



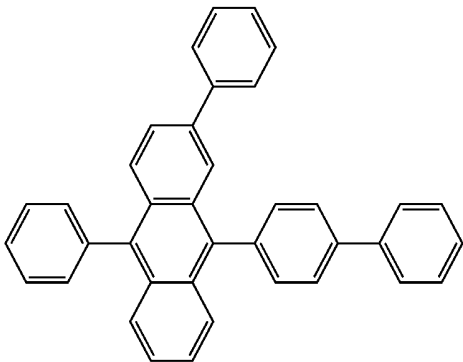
H33



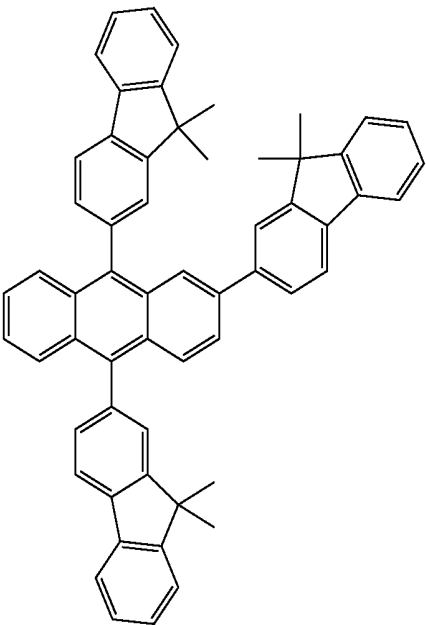
H34



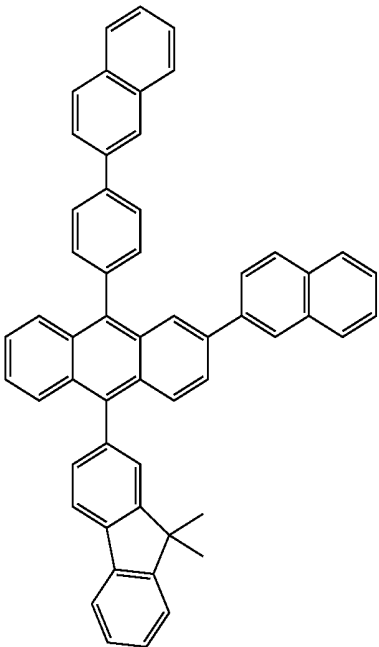
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H35



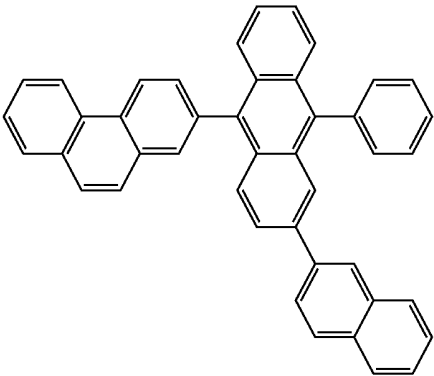
H36



H37

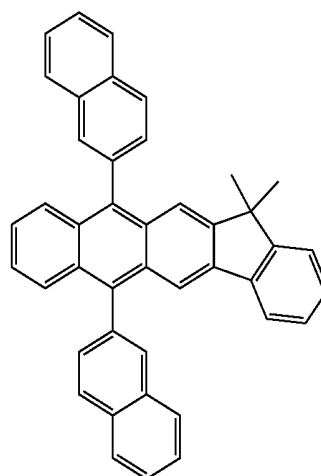
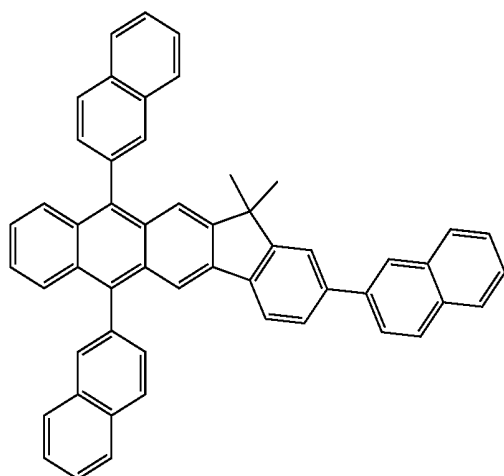


H38



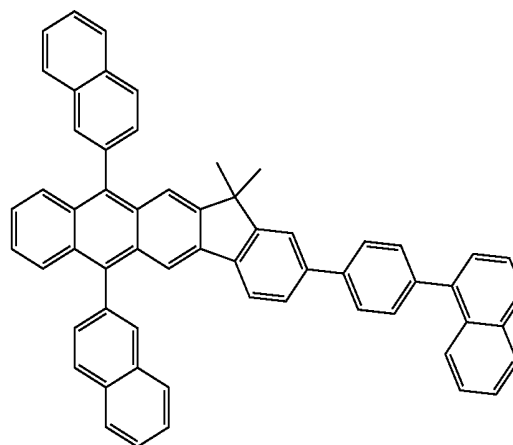
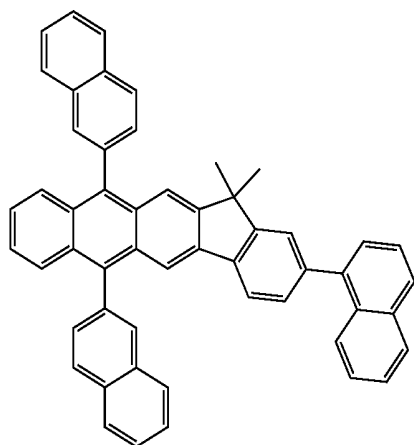
-continued
H39

H40



H41

H42



[0232] 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. According to another embodiment, 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.

[0233] When the emission layer includes a host and a dopant, an 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.

[0234] A thickness of the emission layer may be in a range of about 100 Å to about 1,000 Å, for example, about 200 Å to about 600 Å. When the thickness of the emission layer is within this range, excellent light-emission characteristics may be obtained without a substantial increase in driving voltage.

[0235] Then, an electron transport region may be disposed on the emission layer.

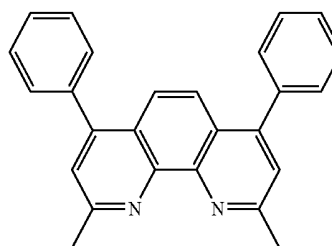
[0236] The electron transport region may include at least one selected from a hole blocking layer, an electron transport layer, and an electron injection layer.

[0237] 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

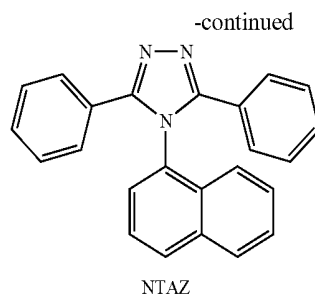
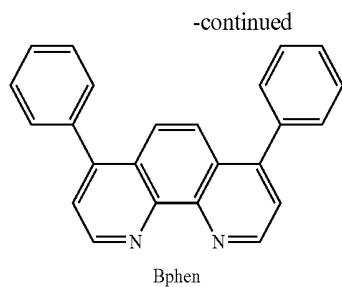
transport region is not limited thereto. The electron transport layer may have a single-layered structure or a multi-layer structure including two or more different materials.

[0238] 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.

[0239] When the electron transport region includes a hole blocking layer, the hole blocking layer, for example, may include at least one selected from BCP and Bphen below, but is not limited thereto.

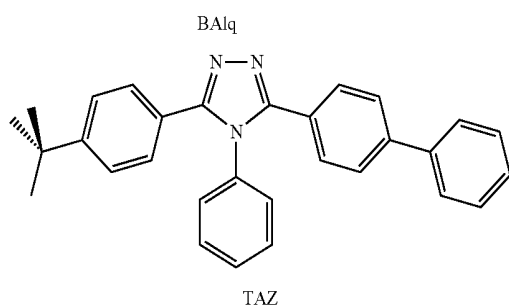
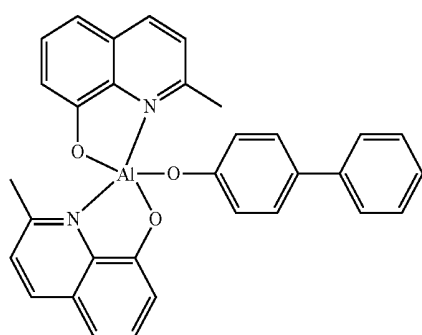
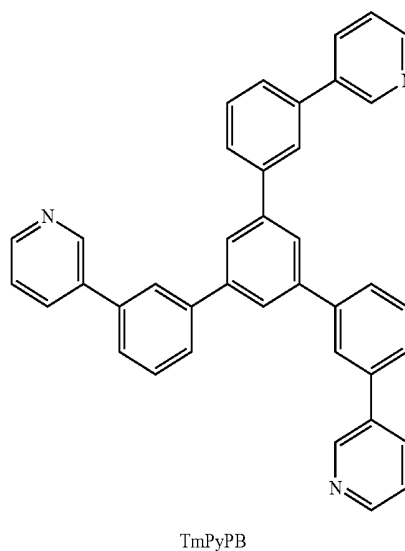
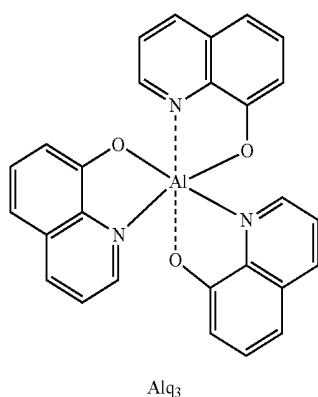


BCP

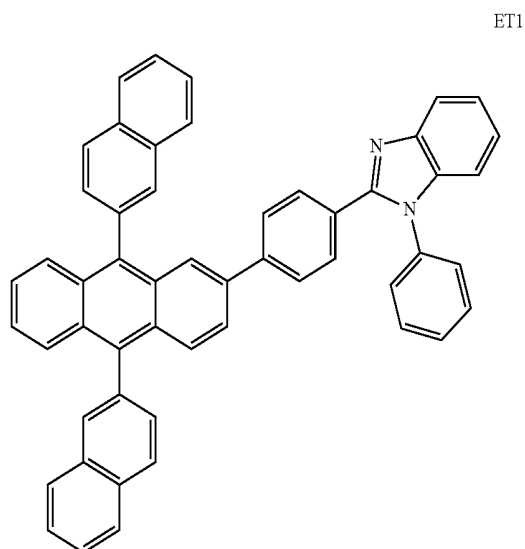


[0240] A thickness of the hole blocking layer may be in a range of about 20 Å to about 1,000 Å, for example, about 30 Å to about 300 Å. When the thickness of the hole blocking layer is within these ranges, the hole blocking layer may have excellent hole blocking characteristics without a substantial increase in driving voltage.

[0241] The electron transport layer may include at least one selected from BCP, Bphen, Alq₃, Balq, TAZ, NTAZ and TmPyPB.

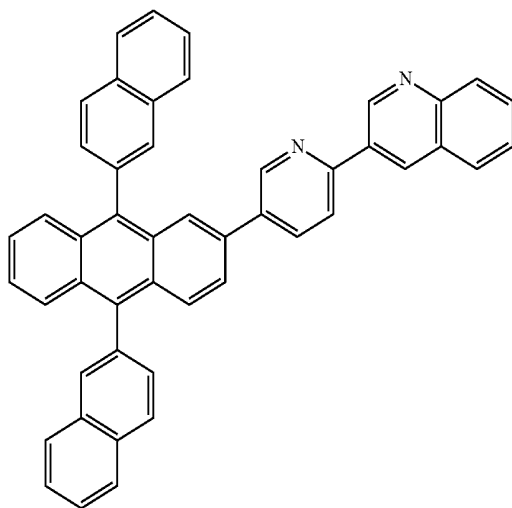


[0242] According to another embodiment, the electron transport layer may include at least one of ET1 and ET2, but are not limited thereto:



-continued

ET2

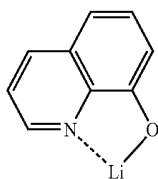


[0243] A thickness of the electron transport layer may be in a range of about 100 Å to about 1,000 Å, for example, about 150 Å to about 500 Å. When the thickness of the electron transport layer is within the range described above, the electron transport layer may have satisfactory electron transport characteristics without a substantial increase in driving voltage.

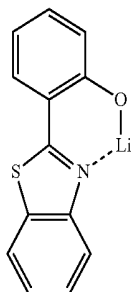
[0244] Also, the electron transport layer may further include, in addition to the materials described above, a metal-containing material.

[0245] 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



[0246] The electron transport region may include an electron injection layer (EIL) that allows electrons to be easily provided from a second electrode 19.

[0247] The electron injection layer may include at least one selected from, LiF, NaCl, CsF, Li₂O, BaO, and LiQ.

[0248] A thickness of the electron injection layer may be in a range of about 1 Å to about 100 Å, for example, about 3 Å to about 90 Å. When the thickness of the electron injection

layer is within the ranges described above, the electron injection layer may have satisfactory electron injection characteristics without a substantial increase in driving voltage.

[0249] 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 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 the material for forming the second electrode 19. 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.

[0250] Hereinbefore, the organic light-emitting device has been described with reference to FIG. 1, but is not limited thereto.

[0251] A C₁-C₆₀ 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 isomethyl group, and a hexyl group. A C₁-C₆₀ alkenylene group as used herein refers to a divalent group having the same structure as the C₁-C₆₀ alkyl group.

[0252] A C₁-C₆₀ alkoxy group as used herein refers to a monovalent group represented by —OA₁₀₁ (wherein A₁₀₁ is the C₁-C₆₀ alkyl group). Detailed examples thereof are a methoxy group, an ethoxy group, and an isopropoxy group.

[0253] A C₂-C₆₀ alkenyl group as used herein refers to a hydrocarbon group formed by substituting at least one carbon double bond in the middle or at the terminal of the C₂-C₆₀ alkyl group. Detailed examples thereof are an ethenyl group, a propenyl group, and a butenyl group. A C₂-C₆₀ alkenylene group as used herein refers to a divalent group having the same structure as the C₂-C₆₀ alkenyl group.

[0254] A C₂-C₆₀ alkynyl group as used herein refers to a hydrocarbon group formed by substituting at least one carbon triple bond in the middle or terminal of the C₂-C₆₀ alkyl group. Detailed examples thereof are an ethynyl group, and a propynyl group. A C₂-C₆₀ alkynylene group as used herein refers to a divalent group having the same structure as the C₂-C₆₀ alkynyl group.

[0255] A C₃-C₁₀ 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 C₃-C₁₀ cycloalkylene group as used herein refers to a divalent group having the same structure as the C₃-C₁₀ cycloalkyl group.

[0256] A C₁-C₁₀ heterocycloalkyl group as used herein refers to a monovalent monocyclic group having at least one hetero atom selected from N, O, P, and S as a ring-forming atom and 1 to 10 carbon atoms. Detailed examples thereof are a tetrahydrofuran group, and a tetrahydrothiophenyl group. A C₁-C₁₀ heterocycloalkylene group as used herein refers to a divalent group having the same structure as the C₁-C₁₀ heterocycloalkyl group.

[0257] A C₃-C₁₀ 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 is not aromatic. Detailed examples thereof are a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. A

C₃-C₁₀ cycloalkenylene group as used herein refers to a divalent group having the same structure as the C₃-C₁₀ cycloalkenyl group.

[0258] A C₁-C₁₀ heterocycloalkenyl group as used herein refers to a monovalent monocyclic group that has at least one hetero atom selected from N, O, P, and S as a ring-forming atom, 1 to 10 carbon atoms, and at least one double bond in its ring. Detailed examples of the C₁-C₁₀ heterocycloalkenyl group are a 2,3-dihydrofuranyl group and a 2,3-dihydrothiophenyl group. A C₁-C₁₀ heterocycloalkenylene group as used herein refers to a divalent group having the same structure as the C₁-C₁₀ heterocycloalkenyl group.

[0259] A C₆-C₆₀ aryl group as used herein refers to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms, and a C₆-C₆₀ 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 C₆-C₆₀ aryl group are a phenyl group, a naphthyl group, an anthracenyl group, a phenanthrenyl group, a pyrenyl group, and a chrysenyl group. When the C₆-C₆₀ aryl group and the C₆-C₆₀ arylene group each include two or more rings, the rings may be fused to each other.

[0260] A C₁-C₆₀ heteroaryl group used herein refers to a monovalent group having a carbocyclic aromatic system that has at least one hetero atom selected from N, O, P, and S as a ring-forming atom, and 1 to 60 carbon atoms. A C₁-C₆₀ 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, and S as a ring-forming atom, and 1 to 60 carbon atoms. Examples of the C₁-C₆₀ 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 C₁-C₆₀ heteroaryl group and the C₁-C₆₀ heteroarylene group each include two or more rings, the rings may be fused to each other.

[0261] A C₆-C₆₀ aryloxy group used herein indicates —OA₁₀₂ (wherein A₁₀₂ is the C₆-C₆₀ aryl group), and a C₆-C₆₀ arylthio group indicates —SA₁₀₃ (wherein A₁₀₃ is the C₆-C₆₀ aryl group).

[0262] 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 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.

[0263] A monovalent non-aromatic condensed heteropolycyclic group as used herein refers to a monovalent group (for example, having 1 to 60 carbon atoms) that has two or more rings condensed to each other, has a heteroatom selected from N, O, P, and S, other than carbon atoms, as a ring forming atom, and 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.

[0264] At least one of substituents of the substituted C₁-C₆₀ alkyl group, the substituted C₂-C₆₀ alkenyl group, the substi-

tuted C₂-C₆₀ alkynyl group, the substituted C₁-C₆₀ alkoxy group, the substituted C₃-C₁₀ cycloalkyl group, the substituted C₁-C₁₀ heterocycloalkyl group, the substituted C₃-C₁₀ cycloalkenyl group, the substituted C₁-C₁₀ heterocycloalkenyl group, the substituted C₆-C₆₀ aryl group, the substituted C₆-C₆₀ aryloxy group, the substituted C₆-C₆₀ arylthio group, the substituted C₁-C₆₀ heteroaryl group, the substituted a monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from

[0265] 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, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group;

[0266] a C₁-C₆₀ alkyl group, a C₃-C₆₀ alkenyl group, a C₃-C₆₀ alkynyl group, and a C₁-C₆₀ 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, a phosphoric acid group or a salt thereof, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q₁₁)(Q₁₂), —Si(Q₁₃)(Q₁₄)(Q₁₅), and —B(Q₁₆)(Q₁₇);

[0267] a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

[0268] a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ 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 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, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group, a C₃-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q₂₁)(Q₂₂), —Si(Q₂₃)(Q₂₄)(Q₂₅) and —B(Q₂₆)(Q₂₇); and

[0269] —N(Q₃₁)(Q₃₂), —Si(Q₃₃)(Q₃₄)(Q₃₅), and —B(Q₃₆)(Q₃₇).

[0270] wherein Q₁ to Q₇, Q₁₁ to Q₁₇, Q₂₁ to Q₂₇, and Q₃₁ to Q₃₇ may be each independently selected from a hydrogen, a

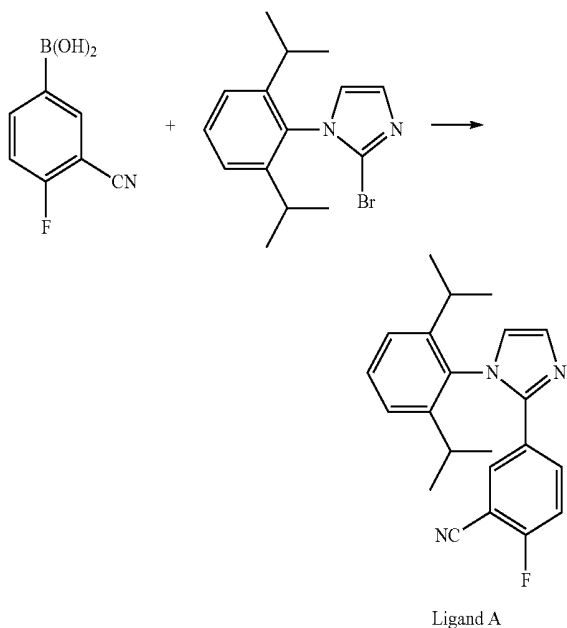
deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

[0271] 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 phrase “B was used instead of A” used in describing Synthesis Examples means that a molar equivalent of A was identical to a molar equivalent of B.

EXAMPLE

Synthesis Example 1

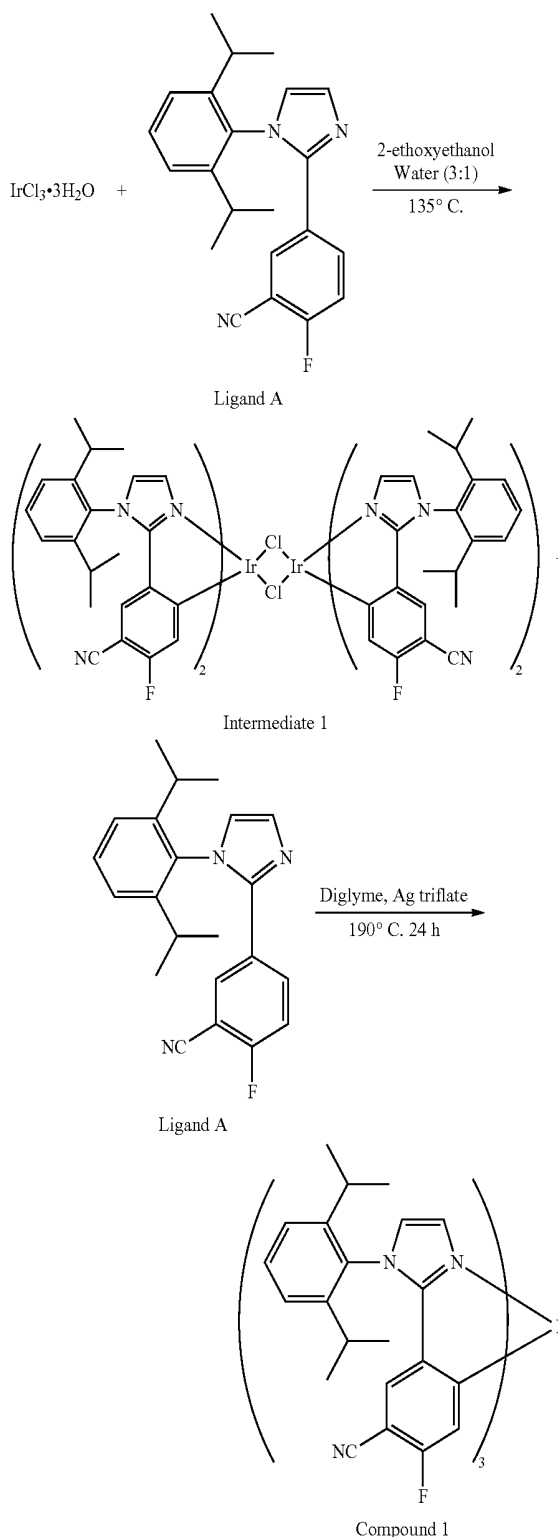
[0272]



[0273] Synthesis of Ligand A

[0274] 30 millimoles (mmol) (9.21 grams (g)) of 2-bromo-1-(2,6-diisopropylphenyl)-1H-imidazole, 45 mmol (7.43 g) of (3-cyano-4-fluorophenyl)boronic acid, 0.9 mmol (1.04 g) of tetrakis-(triphenylphosphine) palladium(0) and 90 mmol (12.42 g) of potassium carbonate in 90 mL of THF, 90 mL of toluene and 60 mL of water were refluxed for 72 hours. The reaction product was cooled and extracted from a mixture of ethyl acetate and water in the organic layer. The organic layer was washed three times with water and dried over magnesium sulfate. The solvent was evaporated at reduced pressure and

the crude product was purified by a column of silica using ethyl acetate and hexane as the eluent to give Ligand A in 60% yield.



[0275] Synthesis of Intermediate 1

[0276] 3 mmol (1.056 g) of IrCl₃·3H₂O and 6 mmol (2.09 g) of the Ligand A were taken in a mixture of 90 milliliters

(mL) of ethoxyethanol and 30 mL of water and refluxed for 24 h. Water was added to the reaction mixture to produce the yellow precipitate of iridium(III) dimer (Intermediate 1). The Intermediate 1 was thoroughly washed with water followed by methanol, dried in vacuum oven at 80° C., and used in the next step.

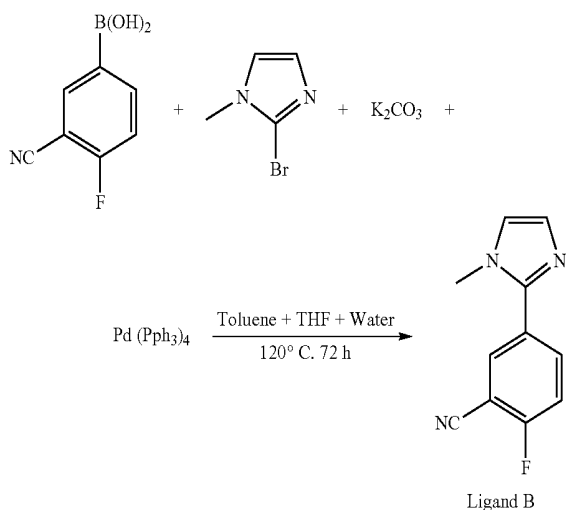
[0277] Synthesis of Compound 1

[0278] 2 mmol (3.682 g) of the Intermediate 1, 4 mmol (1.4 g) of the Ligand A, 2 mmol (0.512 g) of silver triflate were refluxed in 20 mL of diglyme for 24 hours (h). The reaction mixture upon cooling was poured into a large excess of water and extracted with ethyl acetate. The organic layer was washed three times with water and then dried over magnesium sulfate. The solvent was evaporated at reduced pressure and the crude product was purified by a column of silica using ethylacetate and hexane as the eluent to give Compound 1 in 20% yield. The synthesized compound was confirmed by MALDI-TOF and proton NMR spectra.

[0279] MALDI-TOF: 1231 M/Z

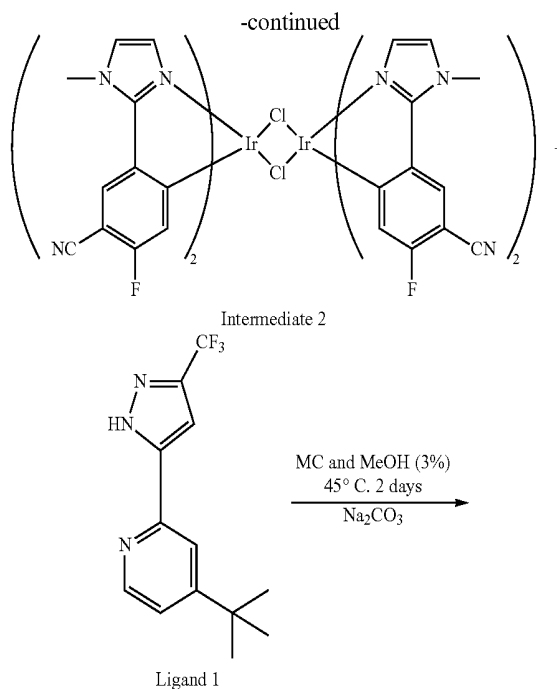
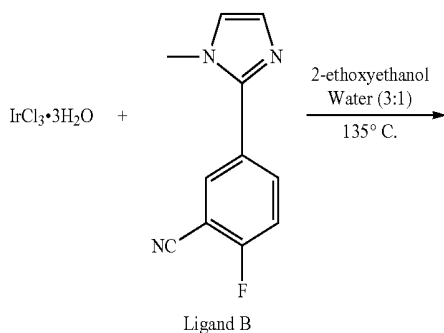
Synthesis Example 2

[0280]



[0281] Synthesis of Ligand B

[0282] Ligand B was synthesized in the same way as Synthesis of Ligand A in Synthesis Example 1, except that, 2-bromo-1-(methyl)-1H-imidazole was used instead of 2-bromo-1-(2,6-diisopropylphenyl)-1H-imidazole. Ligand B was obtained in 60% yield.



[0283] Synthesis of Intermediate 2

[0284] Synthesis of Intermediate 2 was performed in the same way as Synthesis of Intermediate 1 in Synthesis Example 1, except that Ligand B was used instead of Ligand A.

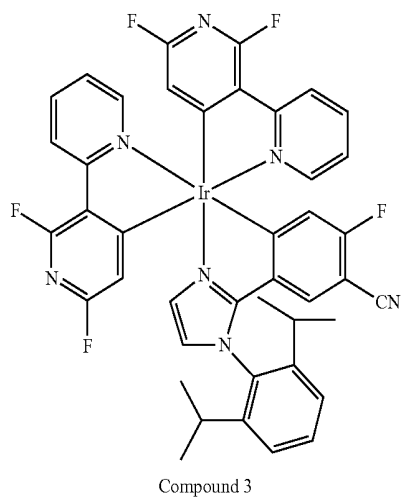
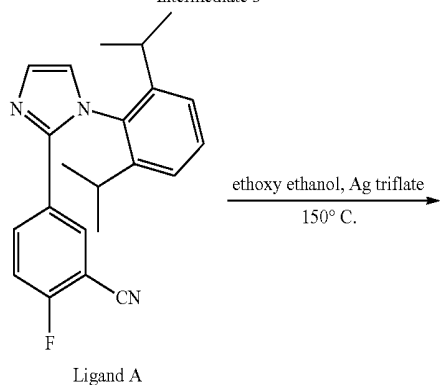
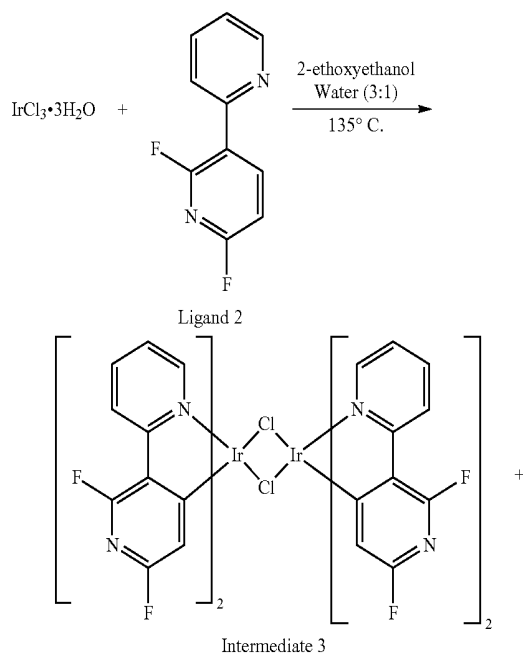
[0285] Synthesis of Compound 2

[0286] 2 mol (2.512 g) of the Intermediate 2, 2.5 mmol (0.673 g) of Ligand 1 (4-(tert-butyl)-2-(3-(trifluoromethyl)-1H-pyrazole-5-yl)pyridine) and 20 mmol (2.12 g) of sodium carbonate were refluxed at 45° C. in 240 mL of methylene chloride and 8 mL of methanol for 2 days. The solvents were evaporated at reduced pressure followed by extraction with methylene chloride and evaporation of the solvent. The crude product was purified by a column of silica using methylene chloride as the eluent followed by solvent evaporation to give Compound 2 in 50% yield. Compound 2 was confirmed by proton NMR and mass spectra.

[0287] MALDI-TOF: 860 M/Z

Synthesis Example 3

[0288]



[0289] Synthesis of Intermediate 3

[0290] Synthesis of Intermediate 3 was performed in the same way as Synthesis of Intermediate 1 in Synthesis Example 1, except that Ligand 2 was used instead of Ligand A.

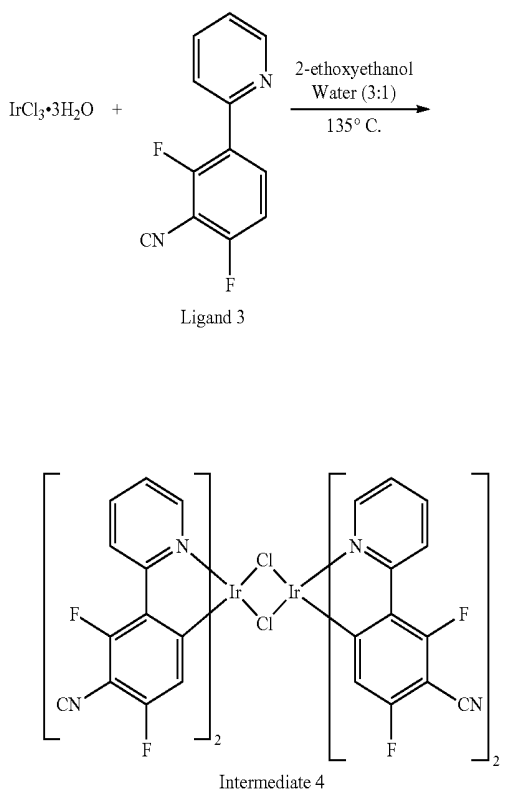
[0291] Synthesis of Compound 3

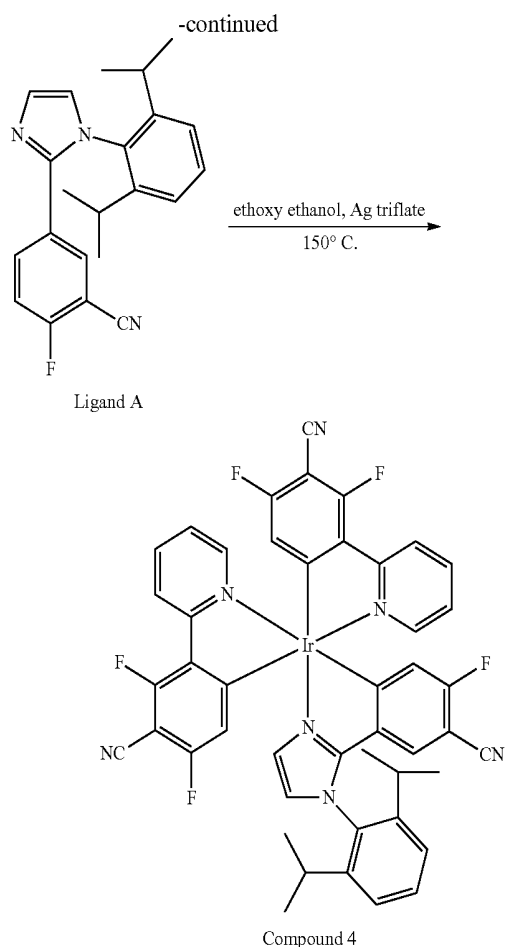
[0292] 2 mol (2.44 g) of the Intermediate 3, 4 mmol (1.4 g) of Ligand A and 2 mmol (0.512 g) of silver triflate were refluxed at 150° C. in 50 mL of ethoxyethanol for 2 days. The solvents were evaporated at reduced pressure followed by extraction with methylene chloride and evaporation of the solvent. The crude product was purified by a column of silica using methylene chloride as the eluent followed by solvent evaporation to give compound 3 in 20% yield. Compound 3 was confirmed by proton NMR and mass spectra.

[0293] MALDI-TOF: 921 M/Z

Synthesis Example 4

[0294]



**[0295]** Synthesis of Intermediate 4

[0296] Synthesis of Intermediate 4 was performed in the same way as Synthesis of Intermediate 1 in Synthesis Example 1, except that Ligand 3 was used instead of Ligand A.

[0297] Synthesis of Compound 4

[0298] 2 mol (2.65 g) of the Intermediate 4, 4 mmol (1.4 g) of Ligand A and 2 mmol (0.512 g) of silver triflate were refluxed at 150° C. in 50 mL of ethoxyethanol for 2 days. The solvents were evaporated at reduced pressure followed by extraction with methylene chloride and evaporation of the solvent. The crude product was purified by a column of silica using methylene chloride as the eluent followed by solvent evaporation to give compound 4 in 20% yield. Compound 4 was confirmed by proton NMR and mass spectra.

[0299] MALDI-TOF: 969 M/Z

Evaluation Example 1

Photoluminescence (PL) spectrum, color coordination, and quantum yields evaluation

[0300] Methods described in Table 2 below were used to measure the photoluminescence (PL) spectrum, color coordination, and quantum yields of each Compounds 1 to 4. The results thereof are shown in Table 3, FIG. 2 (PL spectrum of Compound 1), FIG. 3 (PL spectrum of Compound 2), FIG. 4 (PL spectrum of Compound 3), and FIG. 5 (PL spectrum of Compound 4).

TABLE 2

Photoluminescence spectrum	Each compounds was dissolved in CH ₂ Cl ₂ to a concentration of 10 millimolar (mM) and then an ISC PC1 spectrofluorometer in which a Xenon lamp was mounted was used to measure an in-solution PL spectrum of each compound
Photoluminescence quantum yields (PLQY) and color coordination	A CH ₂ Cl ₂ solution of PMMA and 8 percent by weight (wt %) of each compound were mixed, and a mixture obtained therefrom was coated on a quartz substrate by using a spin coater. The coated substrate was heat-treated in an oven at a temperature of 80° C. and cooled to room temperature to obtain a film. The film was used to evaluate a luminescence quantum yields in film and color coordination in film of each compounds (the luminescence quantum yields in film and color coordination in film of each compounds were evaluated by using a Hamamatsu Photonics absolute PL quantum yield measurement system in which a xenon light source, a monochromator, a photonic multichannel analyzer, and an integrating sphere were mounted, and PLQY measurement software (Hamamatsu Photonics, Ltd., Shizuoka, Japan) was used).

TABLE 3

Compound No.	Maximum emission wavelength (nm)	PLQY (%)	Color coordinate
1	463	90	(0.139, 0.249)
2	457	—	(0.14, 0.24)
3	468	—	(0.14, 0.18)
4	464	—	(0.146, 0.257)

[0301] According to Table 3 and FIGS. 2 to 5, it was confirmed that the Compounds 1 to 4 have excellent light-emission characteristics.

Evaluation Example 2

Thermal Stability Evaluation

[0302] Compound 1 was subjected to thermal analysis (N_2 atmosphere, temperature range: room temperature to $700^\circ C.$ or $800^\circ C.$ ($10^\circ C./min$)-TGA, room temperature to $400^\circ C.$ -DSC, Pan Type: Pt Pan in disposable Al Pan(TGA), disposable Al pan(DSC)) using thermo gravimetric analysis (TGA) and differential scanning calorimetry (DSC), and the obtained results are shown in FIG. 6 (it was determined that a temperature at which a weight of Compound 1 was loss 1% was $377^\circ C.$, and a temperature at which the weight of Compound 1 was loss 5% was $400.9^\circ C.$). According to FIG. 6, it was confirmed that Compound 1 has excellent thermal stability.

Evaluation Example 3

Evaluation on HOMO, LUMO, and T1 Energy Levels

[0303] HOMO, LUMO and T1 energy levels of Compounds 1 and A were evaluated according to the method indicated in Table 4, and results thereof are shown in Table 5.

TABLE 4

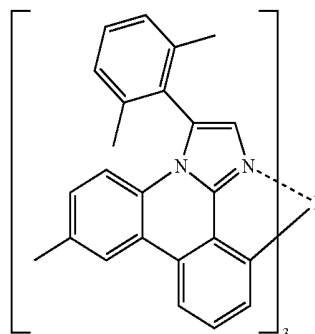
HOMO energy level evaluation method	A potential (Volts, V) - current (Amperes, A) graph of each compound was obtained by using cyclic voltammetry (CV) (electrolyte: 0.1 molar (M) Bu_4NPF_6 /solvent: CH_2Cl_2 /electrode: 3 electrode system (working electrode: Pt disc (1 millimeter (mm) diameter), reference electrode: Pt wire, auxiliary electrode: Pt wire)), and then, 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 $1 \times 10^{-5} M$ 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.
T1 energy level evaluation method	A mixture (each compound was dissolved in an amount of 1 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 ($77 K$). 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 T1 energy levels.

TABLE 5

Compound No.	HOMO (eV) (calc.)	LUMO (eV) (calc.)	T1 energy level (eV)
1	-5.42	-2.75	2.68
A	-5.02	-2.34	2.63

[0304] From Table 5, it was confirmed that Compound 1 has electric characteristics that are suitable to use it as a material for forming an organic light-emitting device in comparison to Compound A.

Compound A



Example 1

[0305] A glass substrate with an 1,500 Å-thick ITO (Indium tin oxide) electrode (first electrode, anode) formed thereon was washed with distilled water in the presence of ultrasonic waves. When the washing with distilled water was completed, sonication washing was performed using a solvent, such as isopropyl alcohol, acetone, or methanol. The result was dried and transferred to a plasma washer, and the resultant substrate was washed with oxygen plasma for 5 minutes and transferred to a vacuum depositing device.

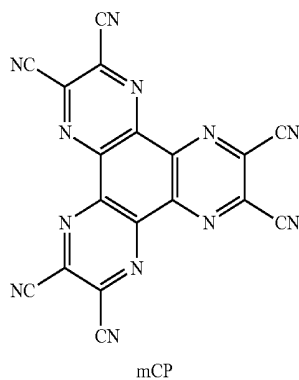
[0306] HAT-CN (Compound 200) was vapor deposited on the ITO electrode to form a hole injection layer of 20 nm and then Compound HT3 was vapor deposited on the hole injection layer to form a hole transport layer of 10 nm, and then mCP was vapor deposited on the hole transport layer to form

an electron blocking layer of 30 nanometers (nm), thereby completing the formation of a hole transport region.

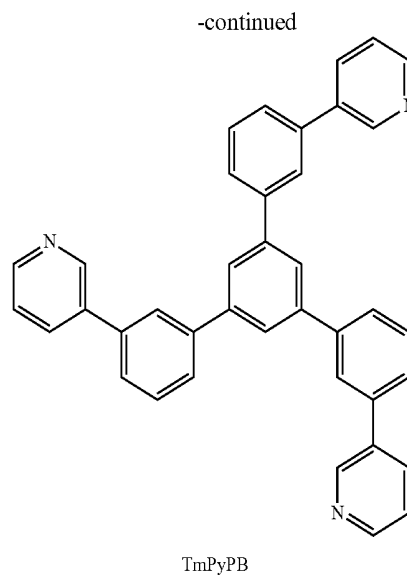
[0307] Compound H50 (host) and Compound 1 (dopant, 10 percent by weight (wt %)) were co-vapor deposited on the hole transport region to form an emission layer of 40 nm.

[0308] TmPyPB was vapor deposited on the emission layer to form an electron transport layer of thickness 20 nm. Then, LiF was vapor deposited on the electron transport layer to

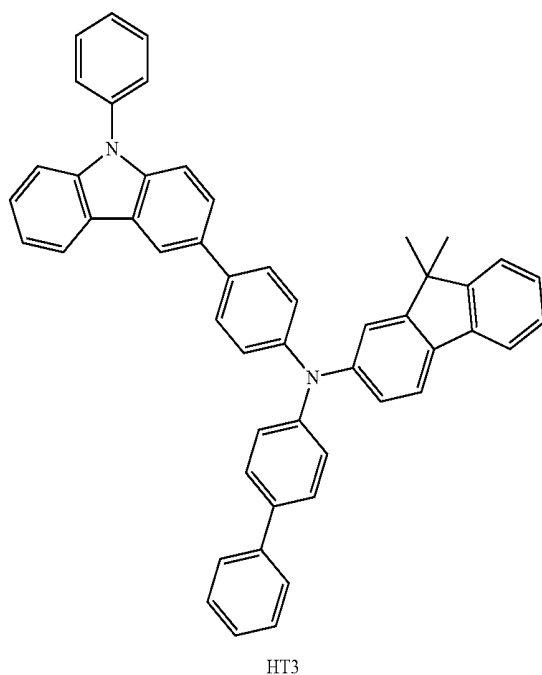
form an electron injection layer of 0.5 nm. Then an Al second electrode (cathode) (100 nm) was formed on the electron injection layer, thereby completing manufacturing of an organic light-emitting device.



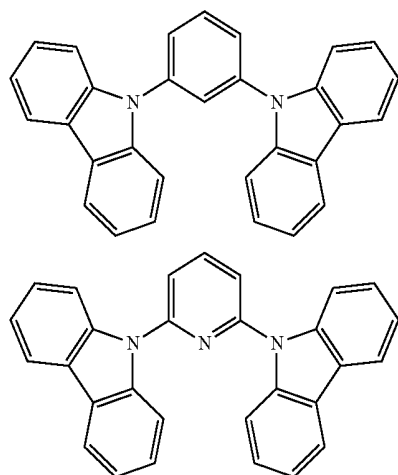
Compound 200



TmPyPB



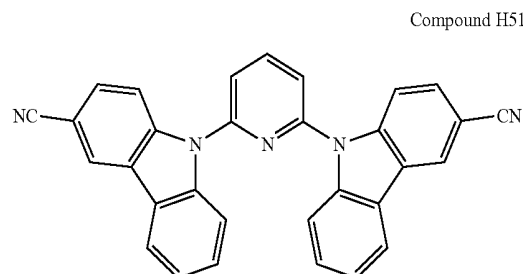
HT3



Compound H50

Example 2

[0309] An organic light-emitting device was manufactured in the same manner as in Example 1, except that in forming an emission layer, as a host, Compound H51 was used instead of Compound H50.



Compound H51

Example 3

[0310] An organic light-emitting device was manufactured in the same manner as in Example 1, except that in forming an emission layer, as a host, Compound H50 and Compound H51 (in a weight ratio of 1:9) were used instead of Compound H50.

Example 4

[0311] An organic light-emitting device was manufactured in the same manner as in Example 3, except that in forming an emission layer, as a host, Compound H50 and Compound H51 (in a weight ratio of 3:7) were used instead of Compound H50.

Example 5

[0312] An organic light-emitting device was manufactured in the same manner as in Example 5, except that in forming an emission layer, as a host, Compound H50 and Compound H51 (in a weight ratio of 5:5) were used instead of Compound H50.

Evaluation Example 3

Evaluation on Characteristics of an Organic Light-Emitting Device

[0313] The driving voltage, power, efficiency, color coordination, quantum yield, and lifespan (T_{95}) of the organic light-emitting devices manufactured according to Examples 1 to 5 were measured. The results thereof are shown in Table 6, Table 7, FIG. 7 (illustrating the relationship between brightness and efficiency/y), and FIG. 8 (illustrating the relationship between time and brightness). A current-voltage meter (Keithley 2400) and luminance meter (Minolta Cs-1000A) were used to evaluate the organic light-emitting devices. Lifespan (T_{95}) indicates a period of time (hours, hrs) taken for the brightness to reach 95% with respect to 100% of initial brightness.

TABLE 6

	Host	Dopant	Driving Voltage (V)	Efficiency (cd/A)	Power (lm/W)	Efficiency/y
Example 1	Compound H50	Compound 1	6.86	14.19	6.51	66.1
Example 2	Compound H51	Compound 1	5.10	39.45	24.34	156.8
Example 3	Compound H50 and H51 (1:9)	Compound 1	5.03	35.37	22.12	155.3
Example 4	Compound H50 and H51 (3:7)	Compound 1	5.55	32.29	18.31	138.8
Example 5	Compound H50 and H51 (5:5)	Compound 1	5.67	27.83	15.49	119.5

TABLE 7

	Host	Dopant	CIEx	CIExy	Quantum yield (%)	Lifespan (hr) (T_{95})
Example 1	Compound H50	Compound 1	0.152	0.215	9.2	0.74
Example 2	Compound H51	Compound 1	0.156	0.252	22.8	0.25
Example 3	Compound H50 and H51 (1:9)	Compound 1	0.155	0.228	21.7	0.64
Example 4	Compound H50 and H51 (3:7)	Compound 1	0.158	0.233	19.4	1.36
Example 5	Compound H50 and H51 (5:5)	Compound 1	0.154	0.233	17.0	4.27

[0314] From Table 6, Table 7, FIG. 7, and FIG. 8, it was confirmed that the organic light-emitting devices of Examples 1 to 5 had low driving voltage, high power, high efficiency, high quantum yields, and long lifespan (T_{95}).

[0315] As described above, according to the one or more of the above exemplary embodiments, the organometallic compound according to embodiments has excellent electric characteristics and thermal stability. Accordingly, an organic light-emitting device including the organometallic compound may have a low driving voltage, high efficiency, high brightness, and a long lifespan.

[0316] It should be understood that the exemplary embodiments described therein 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.

[0317] 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 as defined by the following claims.

What is claimed is:

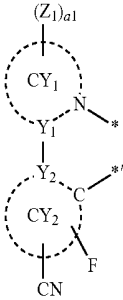
1. An organometallic compound represented by Formula 1:



wherein in Formula 1,

L_1 is a divalent ligand represented by Formula 2,
 L_2 is selected from a monovalent organic ligand, a divalent organic ligand, and trivalent organic ligand, and
 L_2 is not a ligand represented by Formula 2;

Formula 2



wherein in Formula 2,

M is selected from Ir, Pt, Os, Ti, Zr, Hf, Eu, Tb, and Tm;

Y₁ to Y₂ are each independently C or N;

Y₁ and N are linked to each other via a single bond or a double bond, and Y₂ and C are linked to each other via a single bond or a double bond;

CY₁ is a C₁-C₆₀ heterocyclic group;

CY₂ is selected from a C₅-C₆₀ cyclic group and a C₁-C₆₀ heterocyclic group;

CY₁ and CY₂ are optionally additionally linked to each other via a first linking group;

Z₁ is selected from a hydrogen, a deuterium, a hydroxyl 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 substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₂-C₆₀ alkenyl group, a substituted or unsubstituted C₂-C₆₀ alkynyl group, a substituted or unsubstituted C₁-C₆₀ alkoxy group, a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —N(Q₁)(Q₂), —Si(Q₃)(Q₄)(Q₅), and —B(Q₆)(Q₇);

a₁ is an integer selected from 1 to 5, provided that when a₁ is two or more, groups Z₁ are identical or different;

n₁ is an integer selected from 1 to 3, provided that when a₁ is two or more, groups L₁ are identical or different;

n₂ is an integer selected from 0 to 4, provided that when n₂ is two or more, groups L₂ are identical or different;

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

at least one of substituents of the substituted C₁-C₆₀ alkyl group, the substituted C₂-C₆₀ alkenyl group, the substituted C₂-C₆₀ alkynyl group, the substituted C₁-C₆₀ alkoxy group, the substituted C₃-C₁₀ cycloalkyl group, the substituted C₁-C₁₀ heterocycloalkyl group, the substituted C₃-C₁₀ cycloalkenyl group, the substituted C₁-C₁₀ heterocycloalkenyl group, the substituted C₆-C₆₀ aryl group, the substituted C₆-C₆₀ aryloxy group, the substituted C₆-C₆₀ arylthio group, the substituted C₁-C₆₀ heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group is 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, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group;

a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ 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, a phosphoric acid group or a salt thereof, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q₁₁)(Q₁₂), —Si(Q₁₃)(Q₁₄)(Q₁₅), and —B(Q₁₆)(Q₁₇);

a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ 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 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, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q₂₁)(Q₂₂), —Si(Q₂₃)(Q₂₄)(Q₂₅), and —B(Q₂₆)(Q₂₇); and

—N(Q₃₁)(Q₃₂), —Si(Q₃₃)(Q₃₄)(Q₃₅), and —B(Q₃₆)(Q₃₇),

wherein Q₁ to Q₇, Q₁₁ to Q₁₇, Q₂₁ to Q₂₇, and Q₃₁ to Q₃₇ are each independently selected from a hydrogen, 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, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

2. The organometallic compound of claim 1, wherein Y₁ and Y₂ are each C.

3. The organometallic compound of claim 1, wherein

CY₁ is selected from a pyrrole, an imidazole, a pyrazole, a thiazole, an isothiazole, an oxazole, an isoxazole, a tria-

zole, a pyridine, a pyrazine, a pyrimidine, a pyridazine, a quinoline, an isoquinoline, a benzoquinoline, a quinoxaline, a quinazoline, a benzoimidazole, a benzoxazole, an isobenzoxazole, a triazole, a tetrazole, an oxadiazole, and a triazine,

CY₂ is selected from a benzene, a naphthalene, a fluorene, a spiro-fluorene, an indene, a pyrrole, a thiophene, a furan, an imidazole, a pyrazole, a thiazole, an isothiazole, an oxazole, an isoxazole, a triazole, a pyridine, a pyrazine, a pyrimidine, a pyridazine, a quinoline, an isoquinoline, a benzoquinoline, a quinoxaline, a quinazoline, a carbazole, a benzoimidazole, a benzofuran, a benzothiophene, an isobenzothiophene, a benzoxazole, an isobenzoxazole, a triazole, a tetrazole, an oxadiazole, a triazine, a dibenzofuran, and a dibenzothiophene.

4. The organometallic compound of claim 1, wherein CY₁ is selected from an imidazole, a triazole, and a pyridine, CY₂ is selected from a benzene and a pyridine.

5. The organometallic compound of claim 1, wherein Z₁ is selected from

a hydrogen, a deuterium, a hydroxyl 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 C₁-C₂₀ alkyl group, and a C₁-C₂₀ alkoxy group;

a C₁-C₂₀ alkyl group and a C₁-C₂₀ 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, a phosphoric acid group or a salt thereof, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group;

a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl 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 quinolynyl group, an isoquinolynyl group, a benzoquinolynyl group, a quinoxalynyl group, a quinazolynyl group, a cinnolynyl group, a carbazolyl group, a phenanthrolinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzooxazolyl 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 phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl 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 quinolynyl group, an isoquinolynyl group, a benzoquinolynyl group, a quinoxalynyl group, a quinazolynyl group, a cinnolynyl group, a carbazolyl group, a phenanthrolinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzooxazolyl 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, 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 C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl 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 quinolynyl group, an isoquinolynyl group, a benzoquinolynyl group, a quinoxalynyl group, a quinazolynyl group, a cinnolynyl group, a carbazolyl group, a phenanthrolinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and —Si(Q₃₃)(Q₃₄)(Q₃₅); and

Si(Q₃)(Q₄)(Q₅);

Q₃ to Q₅ and Q₃₃ to Q₃₅ are each independently selected from a hydrogen, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl 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 quinolynyl group, an isoquinolynyl group, a benzoquinolynyl group, a quinoxalynyl group, a quinazolynyl group, a cinnolynyl group, a carbazolyl group, a phenanthrolinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzooxazolyl 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.

6. The organometallic compound of claim 1, wherein

Z_1 is selected from

a hydrogen, a nitro group, a methyl group, an ethyl group, a propyl 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-decanyl group, an isodecanyl group, a sec-decanyl group, a tert-decanyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, and a pentoxy group;

a methyl group, an ethyl group, a propyl 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-decanyl group, an isodecanyl group, a sec-decanyl group, a tert-decanyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, and a pentoxy group, each substituted with at least one selected from —F, a cyano group, and a nitro group;

a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, and a dibenzofuran-yl group;

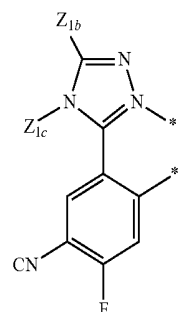
a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group and a dibenzofuran-yl group, each substituted with at least one selected from —F, a cyano group, a nitro group, a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, and —Si(Q_3)(Q_4)(Q_5); and

—Si(Q_3)(Q_4)(Q_5);

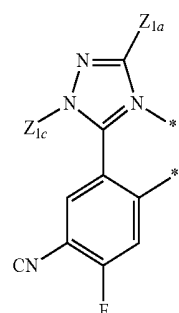
wherein Q_3 to Q_5 and Q_{33} to Q_{35} are each independently selected from a hydrogen, a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, and a triazinyl group.

7. The organometallic compound of claim 1, wherein L_1 is selected from ligands represented by Formulae 2A to 2H:

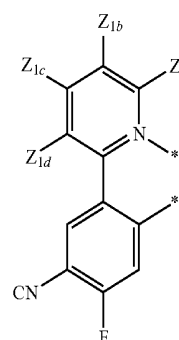
-continued



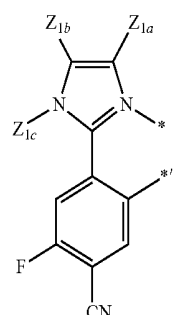
Formula 2B



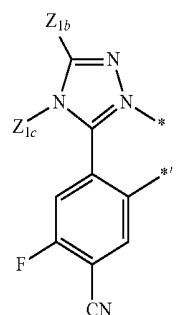
Formula 2C



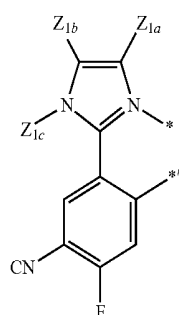
Formula 2D



Formula 2E

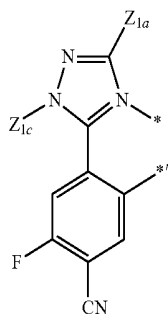


Formula 2F

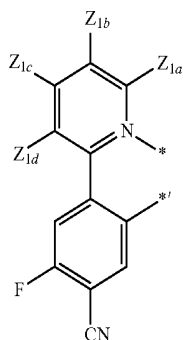


Formula 2A

-continued



Formula 2G



Formula 2H

wherein in Formulae 2A to 2H,

 Z_{1a} to Z_{1d} are each independently selected from

a hydrogen, a nitro group, a methyl group, an ethyl group, a propyl 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-decanyl group, an isodecanyl group, a sec-decanyl group, a tert-decanyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, and a pentoxy group;

a methyl group, an ethyl group, a propyl 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-decanyl group, an isodecanyl group, a sec-decanyl group, a tert-decanyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, and a pentoxy group, each substituted with at least one selected from —F, a cyano group, and a nitro group;

a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, and a dibenzofuran group;

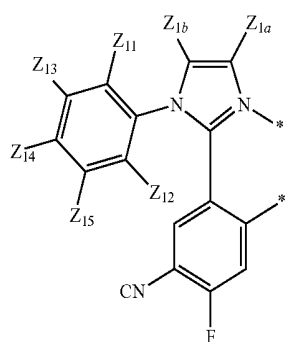
a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group and a dibenzofuran group, each substituted with at least one selected from —F, a cyano group, a nitro group, a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a naph-

thyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, and —Si(Q_{33})(Q_{34})(Q_{35}); and

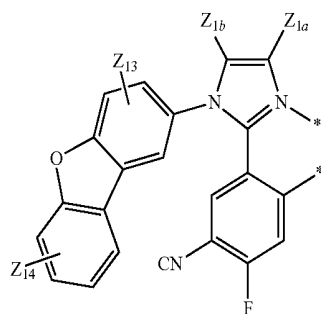
—Si(Q_3)(Q_4)(Q_5);

wherein Q_3 to Q_5 and Q_{33} to Q_{35} are each independently selected from a hydrogen, a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, and a triazinyl group.

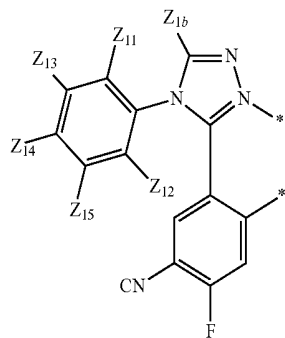
8. The organometallic compound of claim 1, wherein L_1 is selected from ligands represented by Formulae 2A-1 to 2C-1 and 2A-2 to 2C-2:



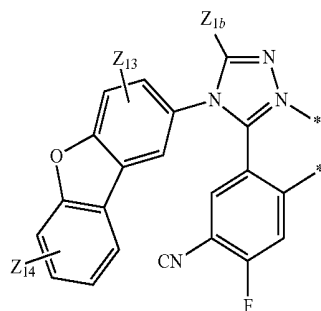
Formula 2A-1



Formula 2A-2

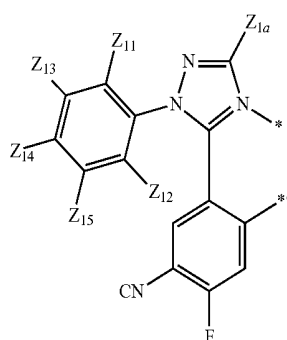


Formula 2B-1

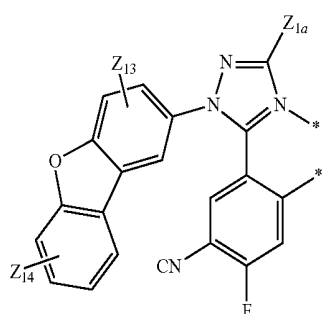


Formula 2B-2

-continued



Formula 2C-1



Formula 2C-2

wherein in Formulae 2A-1 to 2C-1 and 2A-2 to 2C-2,

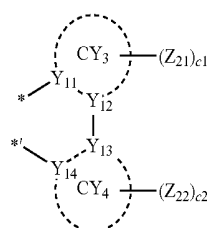
Z_{1a} , Z_{1b} , and Z_{11} to Z_{15} are each independently selected from a hydrogen, a nitro group, a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, and $-\text{Si}(\text{Q}_{33})(\text{Q}_{34})(\text{Q}_{35})$,

wherein Q_{33} to Q_{35} are each independently a hydrogen, a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, and a triazinyl group.

9. The organometallic compound of claim 8, wherein in Formulae 2A-1, 2B-1, and 2C-1, Z_{11} and Z_{12} are each independently selected from a nitro group, a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, and $-\text{Si}(\text{Q}_{33})(\text{Q}_{34})(\text{Q}_{35})$,

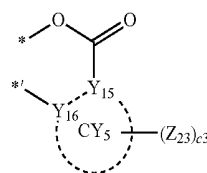
wherein Q_{33} to Q_{35} are each independently a hydrogen, a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, and a triazinyl group.

10. The organometallic compound of claim 1, wherein L_2 in Formula 2 is selected from a ligand represented by Formulae 3-1 to 3-7:

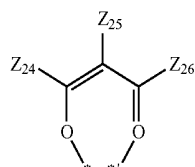


Formula 3-1

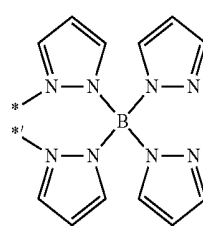
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Formula 3-2



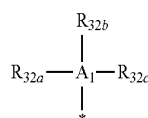
Formula 3-3



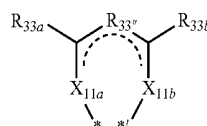
Formula 3-4



Formula 3-5



Formula 3-6



Formula 3-7

wherein in Formulae 3-1 to 3-7,

Y_{11} to Y_{16} are each independently C or N;

CY_3 to CY_5 are each independently selected from a C_5 - C_{60} cyclic group and a C_1 - C_{60} heterocyclic group,

Z_{21} to Z_{26} , R_{31} , R_{32a} , R_{32b} , R_{32c} , R_{33a} , R_{33b} , and R_{34} to R_{38} are each independently selected from a hydrogen, a deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, 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, $-\text{SF}_5$, 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 substi-

tuted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, and $-\text{Si}(\text{Q}_{41})(\text{Q}_{42})(\text{Q}_{43})$;

c1 to c3 are each independently an integer selected from 1 to 5;

A₁ is selected from P and As;

X_{11a} and X_{11b} are each independently selected from N, O, N(R₃₄), P(R₃₅)(R₃₆), and As(R₃₇)(R₃₈);

R_{33a} is selected from a single bond, a double bond, a substituted or unsubstituted C₁-C₅ alkylene group, and a substituted or unsubstituted C₂-C₅ alkenylene group;

wherein Q₄₁ to Q₄₃ are each independently selected from a hydrogen, 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, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

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

11. The organometallic compound of claim 10, wherein CY₃ to CY₅ are each independently selected from a benzene, a naphthalene, a fluorene, a spiro-fluorene, an indene, a pyrrole, a thiophene, a furan, an imidazole, a pyrazole, a thiazole, an isothiazole, an oxazole, an isooxazole, a pyridine, a pyrazine, a pyrimidine, a pyridazine, a quinoline, an isoquinoline, a benzoquinoline, a quinoxaline, a quinazoline, a carbazole, a benzimidazole, a benzofuran, a benzothiophene, an isobenzothiophene, a benzooxazole, an isobenzooxazole, a triazole, a tetrazole, an oxadiazole, a triazine, a dibenzofuran, and a dibenzothiophene.

Z₂₁ to Z₂₆, R₃₁, R_{32a}, R_{32b}, R_{32c}, R_{33a}, R_{33b}, and R₃₄ to R₃₈ are each independently selected from

a hydrogen, 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, a phosphoric acid group or a salt thereof, —SF₅, a C₁-C₂₀ alkyl group, and a C₁-C₂₀ alkoxy group;

a C₁-C₂₀ alkyl group and a C₁-C₆₀ 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, a phosphoric acid group or a salt thereof, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl 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 isooxazolyl group, a pyridinyl group, a pyrazi-

nyl 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 benzooxazolyl group, an isobenzooxazolyl 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 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 isooxazolyl 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 benzooxazolyl group, an isobenzooxazolyl 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, and an imidazopyridinyl 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, a phosphoric acid group or a salt thereof, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy 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, a pyrazolyl group, an oxazolyl group, an isooxazolyl 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 benzooxazolyl 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

$-\text{Si}(\text{Q}_{41})(\text{Q}_{42})(\text{Q}_{43})$;

c1 to c3 are each independently selected from 1, 2, and 3;

X_{11a} and X_{11b} are each independently selected from 0, P(R₃₅)(R₃₆), and As(R₃₇)(R₃₈);

R₃₃" is selected from a single bond, a double bond, a substituted or unsubstituted C₁-C₂ alkylene group, and a substituted or unsubstituted C₂ alkenylene group;

wherein Q₄₁ to Q₄₃ are each independently a hydrogen, a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, and a triazinyl group.

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

L₂ is selected from a ligand represented by Formulae 3-1 to 3-4,

CY₃ is selected from a pyridine, an imidazole, a pyrazole, a triazole, and a tetrazole;

CY₄ is selected from a benzene, a pyridine, a pyrimidine, and a triazine;

CY₅ is selected from a benzene and a pyridine;

Y₁₁ is N;

Y₁₂, Y₁₃, and Y₁₅ are C;

Y₁₄ and Y₁₆ are each independently selected from N and C;

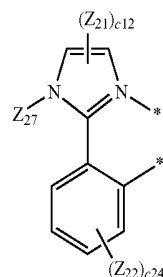
Z₂₁ to Z₂₆ are each independently selected from

a hydrogen, —F, a cyano group, a nitro group, —SF₅, a methyl group, an ethyl group, a propyl 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-decanyl group, an isodecanyl group, a sec-decanyl group, a tert-decanyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

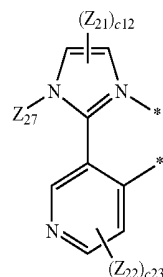
a methyl group, an ethyl group, a propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an isohexyl group, a sec-hexyl group, a tert-hexyl group, an 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-decanyl group, an isodecanyl group, a sec-decanyl group, a tert-decanyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from —F, a cyano group, and a nitro group;

wherein c1 to c3 are each independently selected from 1, 2, and 3.

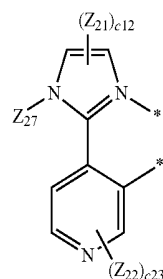
13. The organometallic compound of claim **1**, wherein L₂ is selected from a ligand represented by Formulae 4-1 to 4-106:



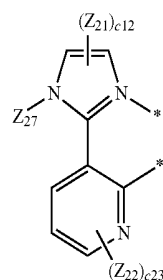
Formula 4-1



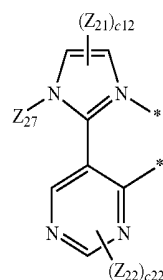
Formula 4-2



Formula 4-3

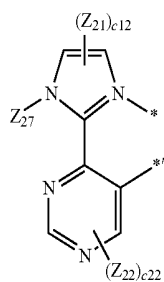


Formula 4-4



Formula 4-5

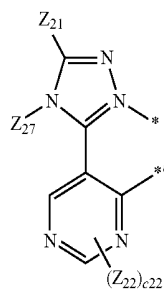
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Formula 4-6

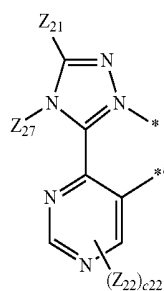
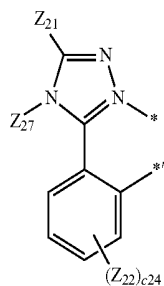
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Formula 4-11



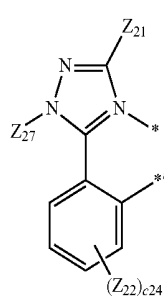
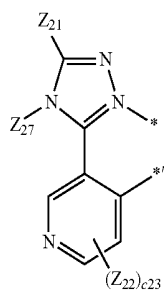
Formula 4-7

Formula 4-12



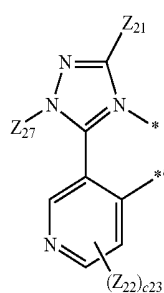
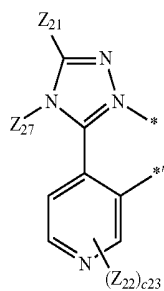
Formula 4-8

Formula 4-13



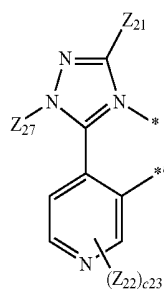
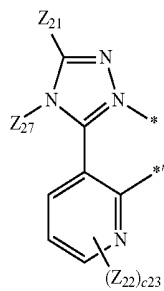
Formula 4-9

Formula 4-14

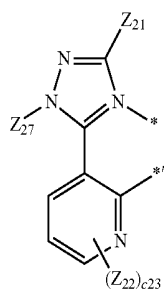


Formula 4-10

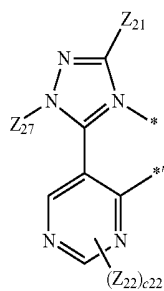
Formula 4-15



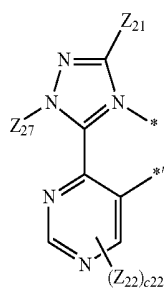
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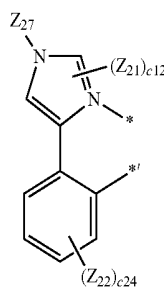
Formula 4-16



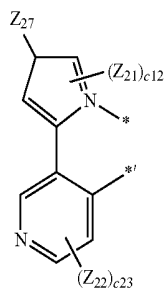
Formula 4-17



Formula 4-18

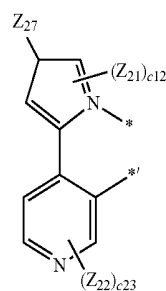


Formula 4-19

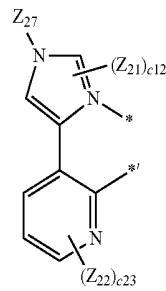


Formula 4-20

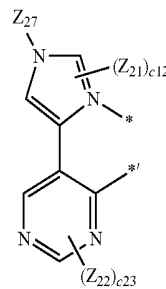
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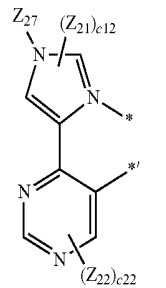
Formula 4-21



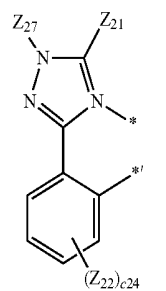
Formula 4-22



Formula 4-23

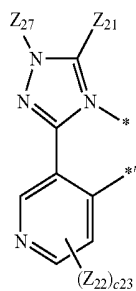


Formula 4-24

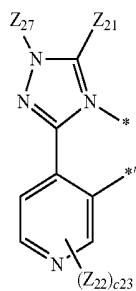


Formula 4-25

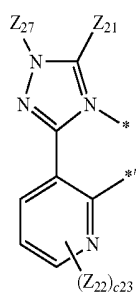
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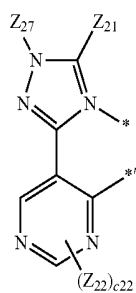
Formula 4-26



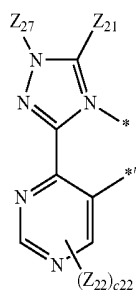
Formula 4-27



Formula 4-28

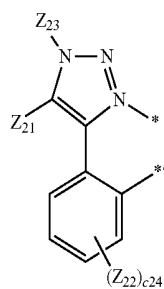


Formula 4-29

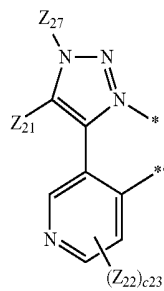


Formula 4-30

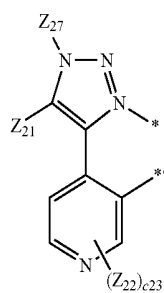
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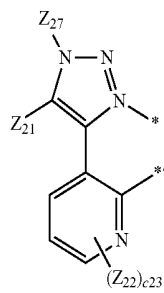
Formula 4-31



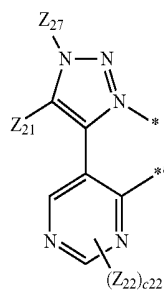
Formula 4-32



Formula 4-33

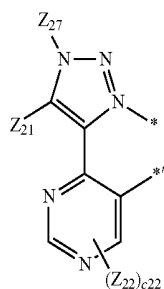


Formula 4-34

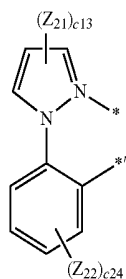


Formula 4-35

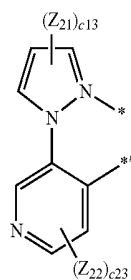
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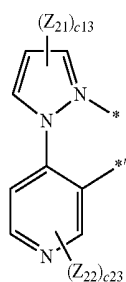
Formula 4-36



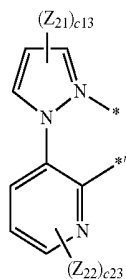
Formula 4-37



Formula 4-38

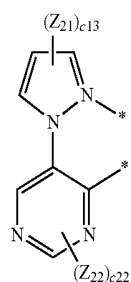


Formula 4-39

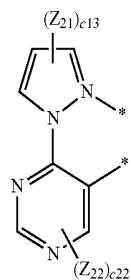


Formula 4-40

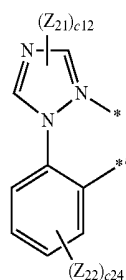
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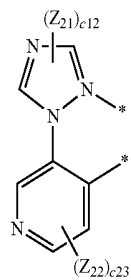
Formula 4-41



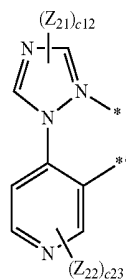
Formula 4-42



Formula 4-43

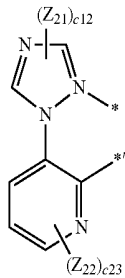


Formula 4-44

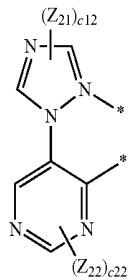


Formula 4-45

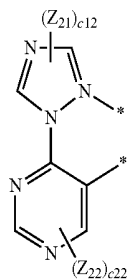
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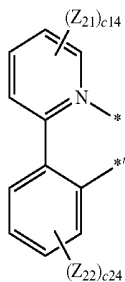
Formula 4-46



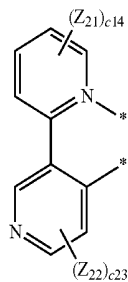
Formula 4-47



Formula 4-48

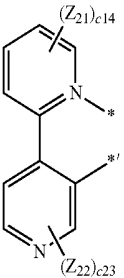


Formula 4-49

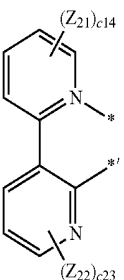


Formula 4-50

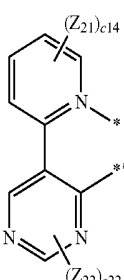
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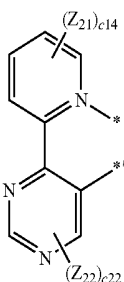
Formula 4-51



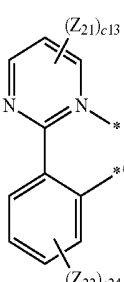
Formula 4-52



Formula 4-53

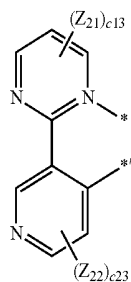


Formula 4-54

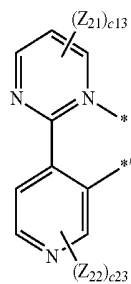


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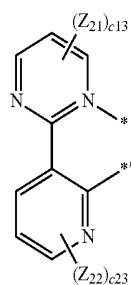
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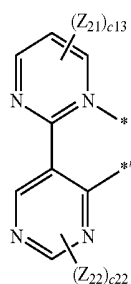
Formula 4-56



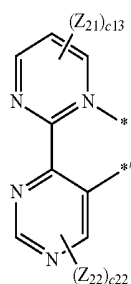
Formula 4-57



Formula 4-58

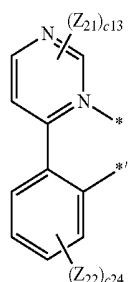


Formula 4-59

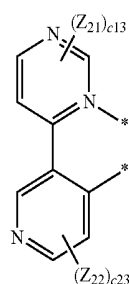


Formula 4-60

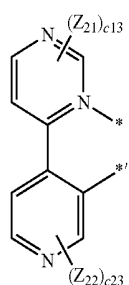
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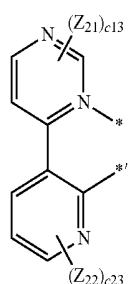
Formula 4-61



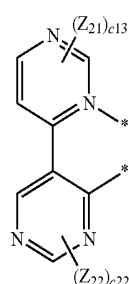
Formula 4-62



Formula 4-63

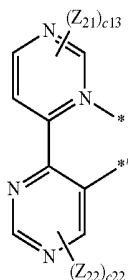


Formula 4-64

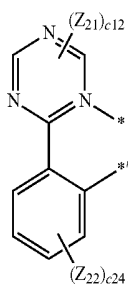


Formula 4-65

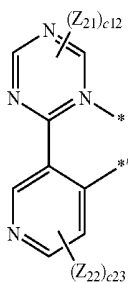
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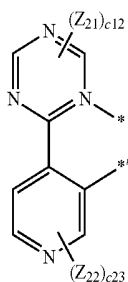
Formula 4-66



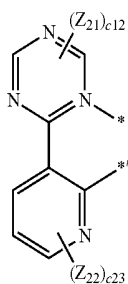
Formula 4-67



Formula 4-68

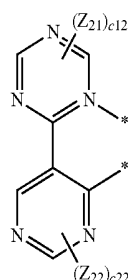


Formula 4-69

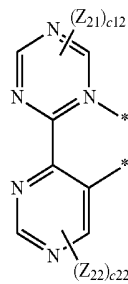


Formula 4-70

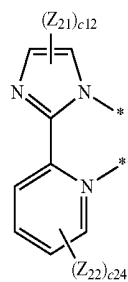
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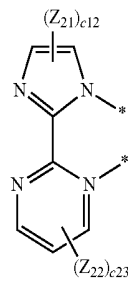
Formula 4-71



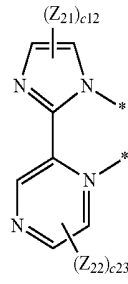
Formula 4-72



Formula 4-73

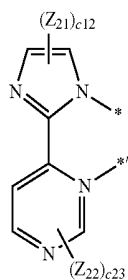


Formula 4-74

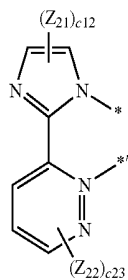


Formula 4-75

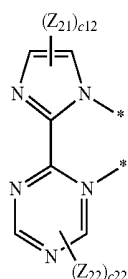
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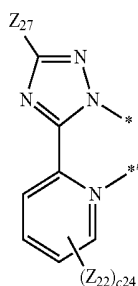
Formula 4-76



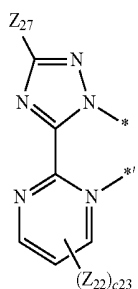
Formula 4-77



Formula 4-78

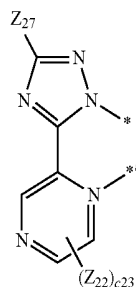


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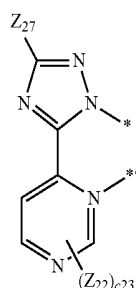


Formula 4-80

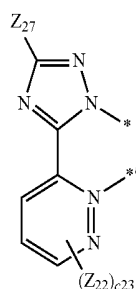
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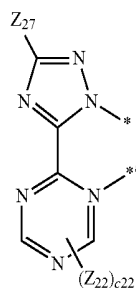
Formula 4-81



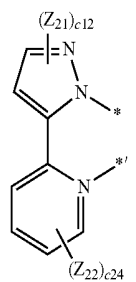
Formula 4-82



Formula 4-83

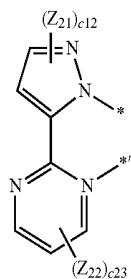


Formula 4-84

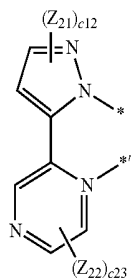


Formula 4-85

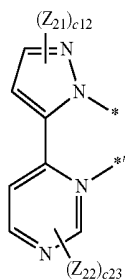
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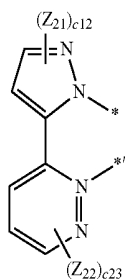
Formula 4-86



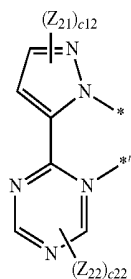
Formula 4-87



Formula 4-88

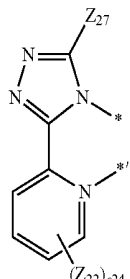


Formula 4-89

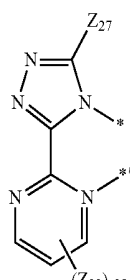


Formula 4-90

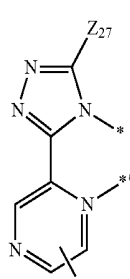
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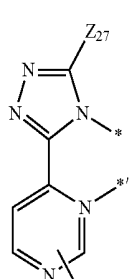
Formula 4-91



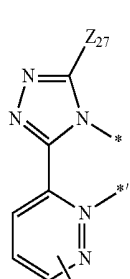
Formula 4-92



Formula 4-93

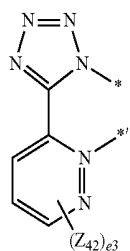
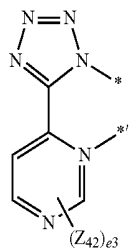
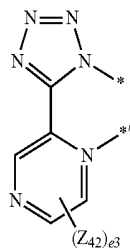
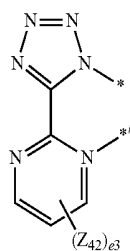
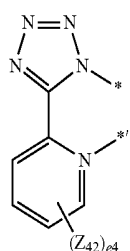
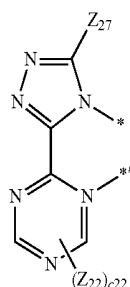


Formula 4-94



Formula 4-95

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Formula 4-96

Formula 4-97

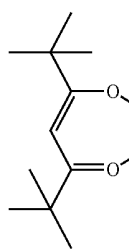
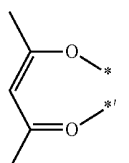
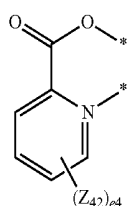
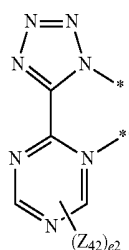
Formula 4-98

Formula 4-99

Formula 4-100

Formula 4-102

-continued



Formula 4-103

Formula 4-104

Formula 4-104

Formula 4-105

wherein in Formulae 4-1 to 4-106,

Z_{21} to Z_{23} , and Z_{27} are each independently selected from a hydrogen, —F, a cyano group, a nitro group, —SF₅, a methyl group, an ethyl group, a propyl 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-decanyl group, an isodecanyl group, a sec-decanyl group, a tert-decanyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and a methyl group, an ethyl group, a 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-decanyl group, an isode-

canyl group, a sec-decanyl group, a tert-decanyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from —F, a cyano group, and a nitro group;

c12 and c22 are each independently selected from 1 and 2, c13 and c23 are each independently selected from 1, 2, and 3, c14 and c24 are each independently selected from 1, 2, 3, and 4;

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

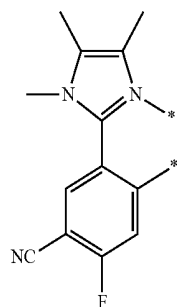
14. The organometallic compound of claim 1, wherein

L₁ is selected from a ligand represented by Formulae 2(1) to 2(10), and

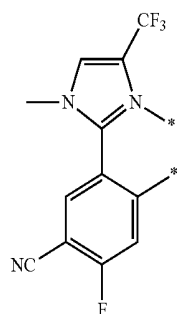
L₂ is selected from a ligand represented by Formulae 3-1 (1) to 3-1(68),

-continued

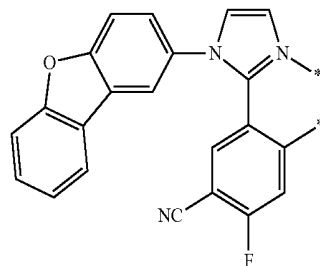
Formula 2(4)



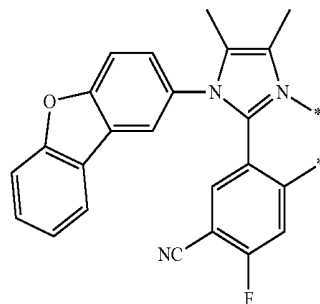
Formula 2(5)



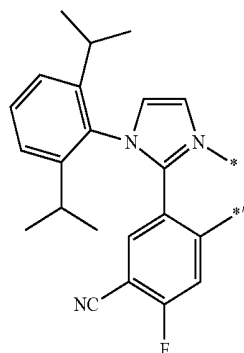
Formula 2(6)



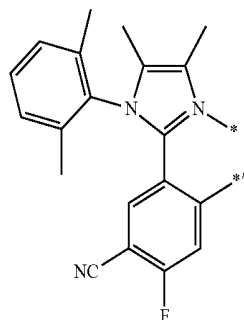
Formula 2(7)



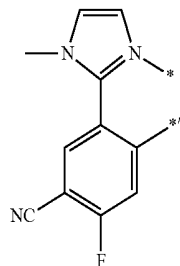
Formula 2(1)



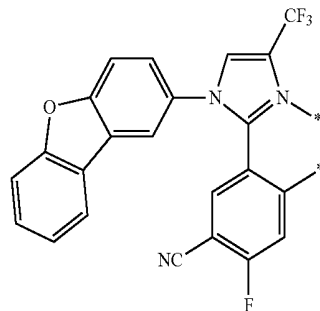
Formula 2(2)



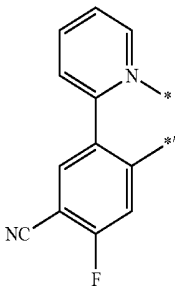
Formula 2(3)



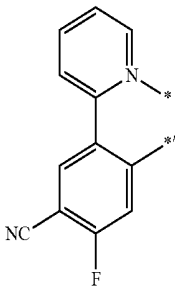
Formula 2(8)



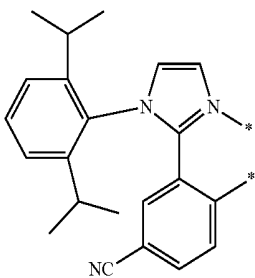
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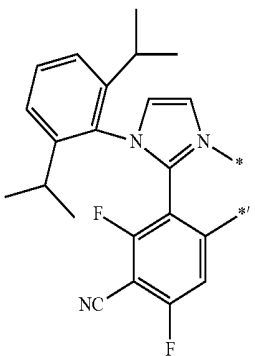
Formula 2(9)



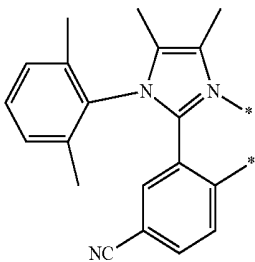
Formula 2(10)



Formula 3-1(1)

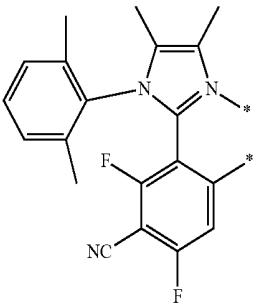


Formula 3-1(2)

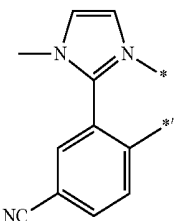


Formula 3-1(3)

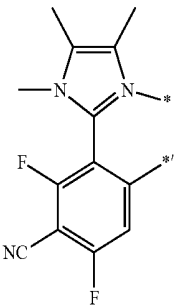
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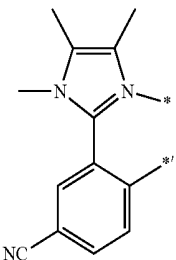
Formula 3-1(4)



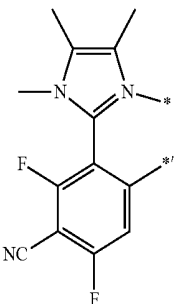
Formula 3-1(5)



Formula 3-1(6)

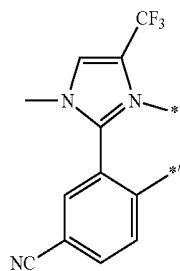


Formula 3-1(7)

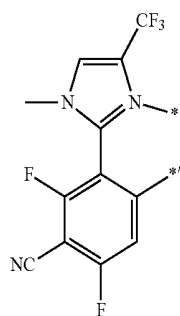


Formula 3-1(8)

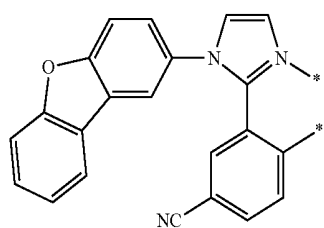
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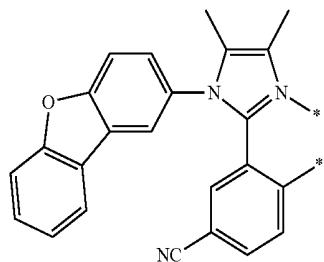
Formula 3-1(9)



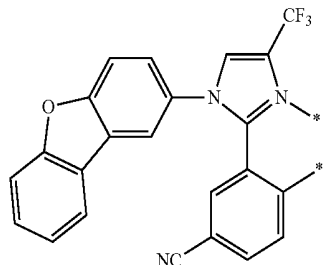
Formula 3-1(10)



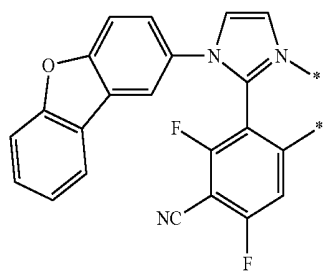
Formula 3-1(11)



Formula 3-1(12)

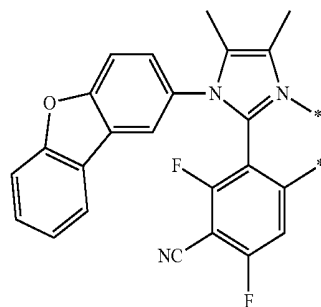


Formula 3-1(13)

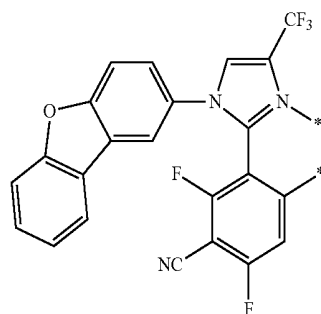


Formula 3-1(14)

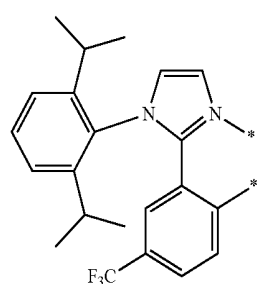
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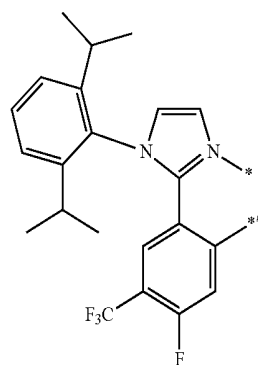
Formula 3-1(15)



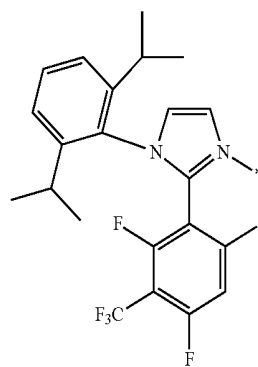
Formula 3-1(16)



Formula 3-1(17)

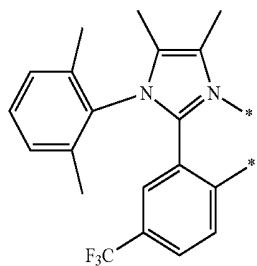


Formula 3-1(18)

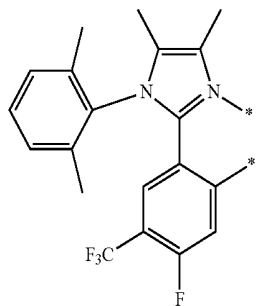


Formula 3-1(19)

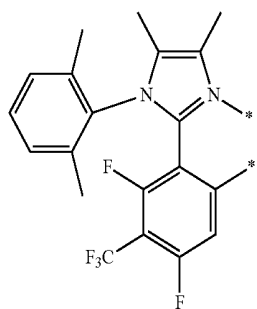
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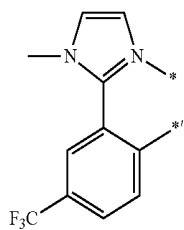
Formula 3-1(20)



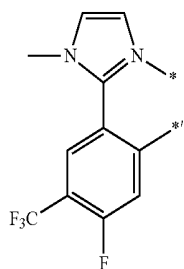
Formula 3-1(21)



Formula 3-1(22)

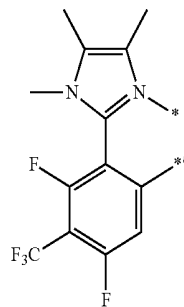


Formula 3-1(23)

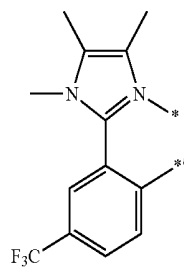


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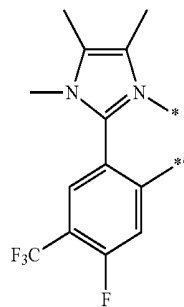
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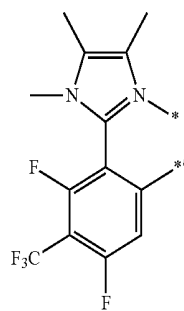
Formula 3-1(25)



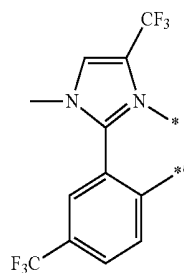
Formula 3-1(26)



Formula 3-1(27)

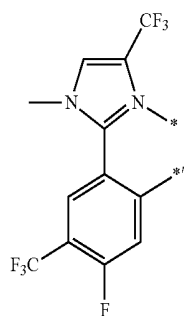


Formula 3-1(28)

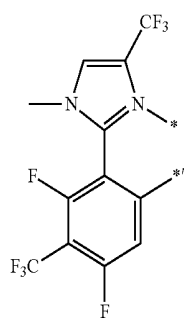


Formula 3-1(29)

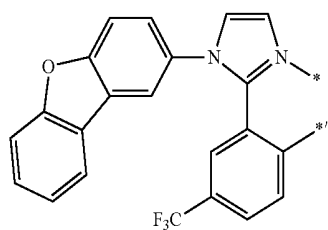
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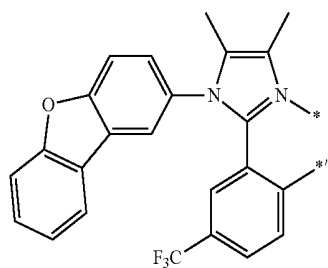
Formula 3-1(30)



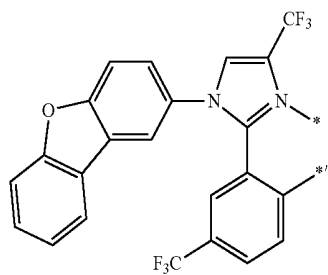
Formula 3-1(31)



Formula 3-1(32)

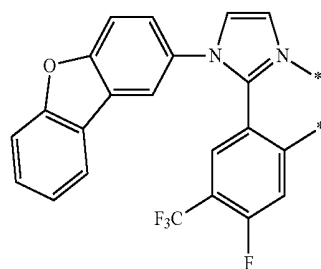


Formula 3-1(33)

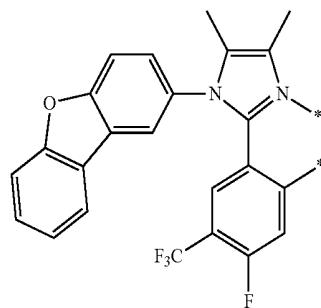


Formula 3-1(34)

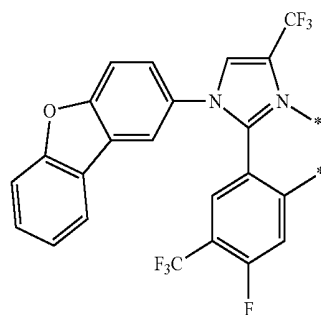
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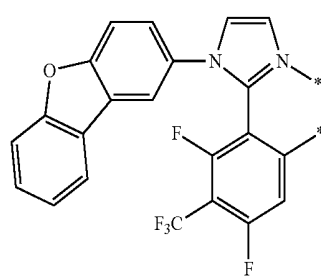
Formula 3-1(35)



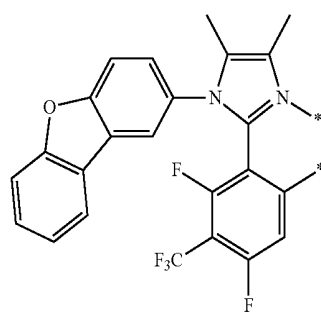
Formula 3-1(36)



Formula 3-1(37)



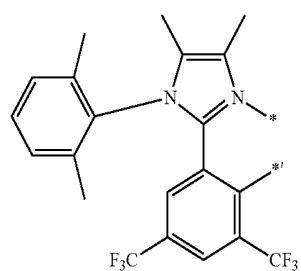
Formula 3-1(38)



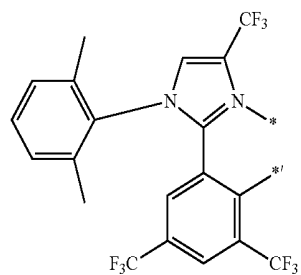
Formula 3-1(39)

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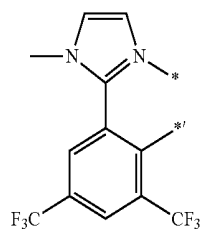
Formula 3-1(45)



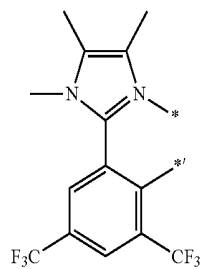
Formula 3-1(46)



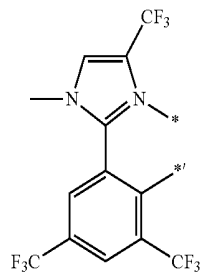
Formula 3-1(47)



Formula 3-1(48)

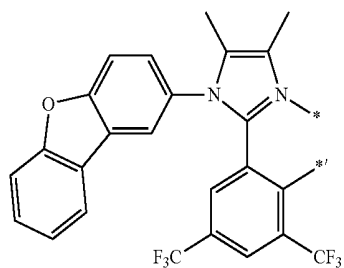


Formula 3-1(49)



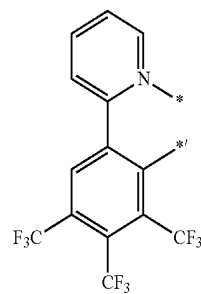
Formula 3-1(50)

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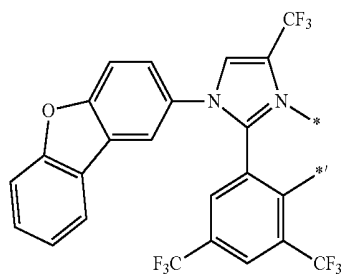
Formula 3-1(51)

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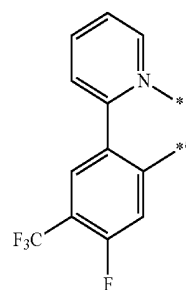


Formula 3-1(56)

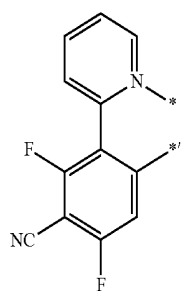
Formula 3-1(52)



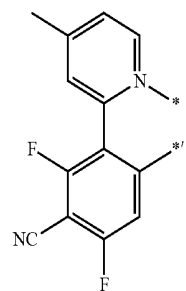
Formula 3-1(53)



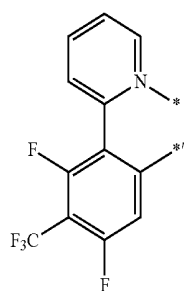
Formula 3-1(57)



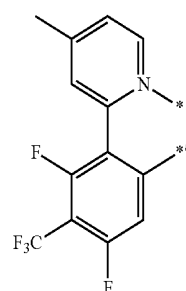
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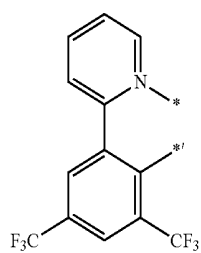
Formula 3-1(58)



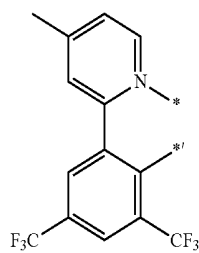
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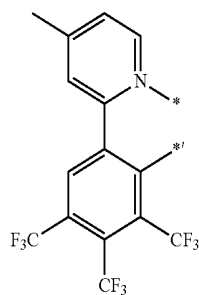
Formula 3-1(59)



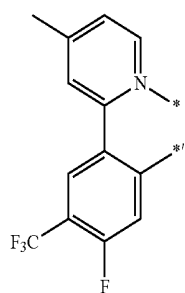
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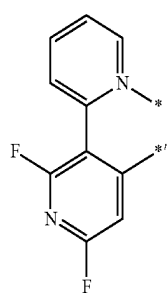
Formula 3-1(60)



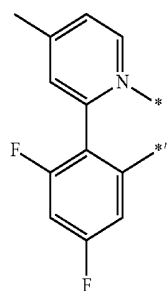
Formula 3-1(61)



Formula 3-1(62)

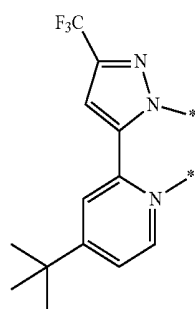


Formula 3-1(63)

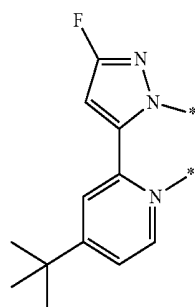


Formula 3-1(64)

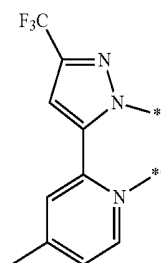
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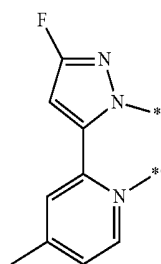
Formula 3-1(65)



Formula 3-1(66)



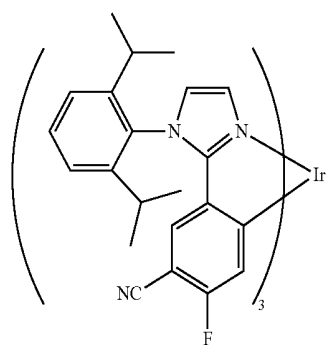
Formula 3-1(67)



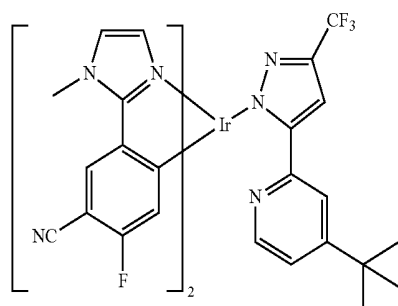
Formula 3-1(68)

15. The organometallic compound of claim 1, wherein n1 is 3, and all three groups L₁ are all identical to each other; or n2 is 2, and both groups L₁ are identical to each other.

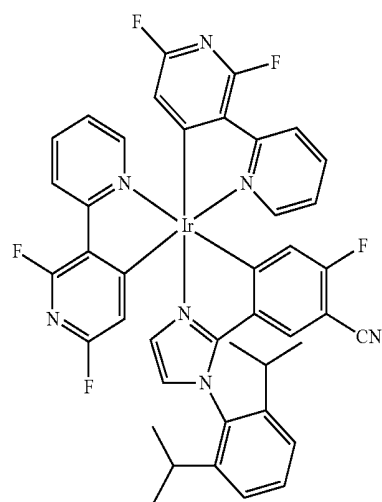
16. The organometallic compound of claim 1, wherein the organometallic compound is one of Compounds 1 to 4:



Compound 1



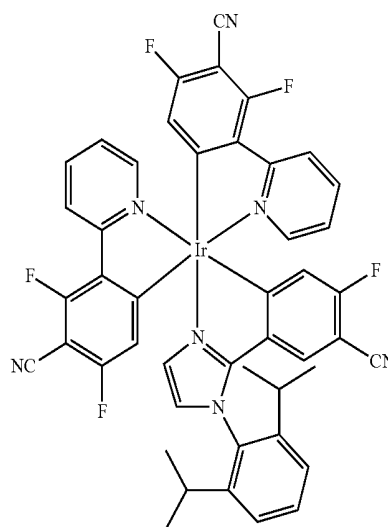
Compound 2



Compound 3

-continued

Compound 4



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, and the organic layer comprises

- i) a hole transport region disposed between the first electrode and the emission layer, wherein the hole transport region comprises at least one of a hole injection layer, a hole transport layer, and an electron blocking layer, and
- ii) an electron transport region disposed between the emission layer and the second electrode, 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 organometallic compound of claim 1, the emission layer further comprises a host, and an amount of the organometallic compound of claim 1 is smaller than an amount of the host.

20. The organic light-emitting device of claim 17, wherein the organic light-emitting device emits deep blue light that has a maximum emission wavelength of about 435 nanometers to about 500 nanometers, an x color coordinate of about 0.14 to about 0.20, and a y color coordinate of about 0.10 to about 0.35.

* * * * *

专利名称(译)	有机金属化合物和包括其的有机发光器件		
公开(公告)号	US20160028024A1	公开(公告)日	2016-01-28
申请号	US14/713435	申请日	2015-05-15
[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. 三星SDI CO. , LTD.		
当前申请(专利权)人(译)	SAMSUNG ELECTRONICS CO. , LTD. 三星SDI CO. , LTD.		
[标]发明人	DAS RUPASREE RAGINI NOH CHANGHO LEE KANG MUN RAI VIRENDRA KUMAR KRAVCHUK DMITRY		
发明人	DAS, RUPASREE RAGINI NOH, CHANGHO LEE, KANG MUN RAI, VIRENDRA KUMAR KRAVCHUK, DMITRY		
IPC分类号	H01L51/00 C07F15/00 C09K11/06		
CPC分类号	H01L51/0085 C07F15/0033 C09K11/06 C09K2211/185 C09K2211/1074 H01L51/5092 H01L51/5056 H01L51/5088 H01L51/5096 H01L51/5072 H01L51/5012 C09K2211/1007 C09K2211/1029 C09K2211/1044 H01L51/006 H01L51/0067 H01L51/0072 H01L51/5016 H01L2251/5384		
优先权	1020140094156 2014-07-24 KR 1020150006120 2015-01-13 KR		
外部链接	Espacenet USPTO		

摘要(译)

由式1表示的有机金属化合物： $M(L_1)_{n1}(L_2)_{n2}$ 式1 其中在式1中， L_1 是由式2表示的二价配体， L_2 选自一价有机配体，二价有机配体和三价有机配体，并且 L_2 不是由式2表示的配体；其中在式1和式2中， M ， CY_1 ， CY_2 ， Y_1 ， Y_2 ， Z_1 ， a_1 ， n_1 和 n_2 与说明书中描述的相同。

