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Lee et al.

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(54) **ORGANOMETALLIC COMPOUND, ORGANIC LIGHT EMITTING DEVICE, AND COMPOSITION FOR DIAGNOSING INCLUDING ORGANOMETALLIC COMPOUND**

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C07F 15/00 (2006.01)
H01L 51/50 (2006.01)

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CPC **H01L 51/0087** (2013.01); **C07F 15/0086** (2013.01); **C09K 11/06** (2013.01); **H01L 51/0094** (2013.01); **C09K 2211/1007** (2013.01); **C09K 2211/1011** (2013.01); **C09K 2211/1044** (2013.01); **C09K 2211/185** (2013.01); **H01L 51/5016** (2013.01)

(58) **Field of Classification Search**
CPC combination set(s) only.
See application file for complete search history.

(56) **References Cited**
U.S. PATENT DOCUMENTS

8,389,725	B2	3/2013	Li et al.	
8,962,838	B2	2/2015	De Cola et al.	
2007/0296329	A1	12/2007	Sotoyama et al.	
2011/0028723	A1*	2/2011	Li	C07F 15/0086 546/4

FOREIGN PATENT DOCUMENTS

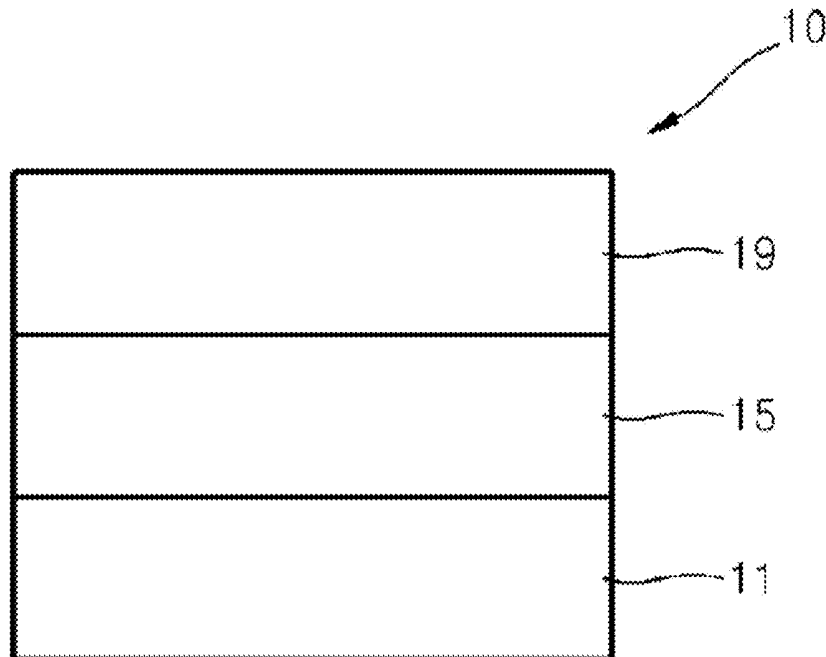
JP	2008-069268	A	3/2008
WO	2012-117082	A1	9/2012

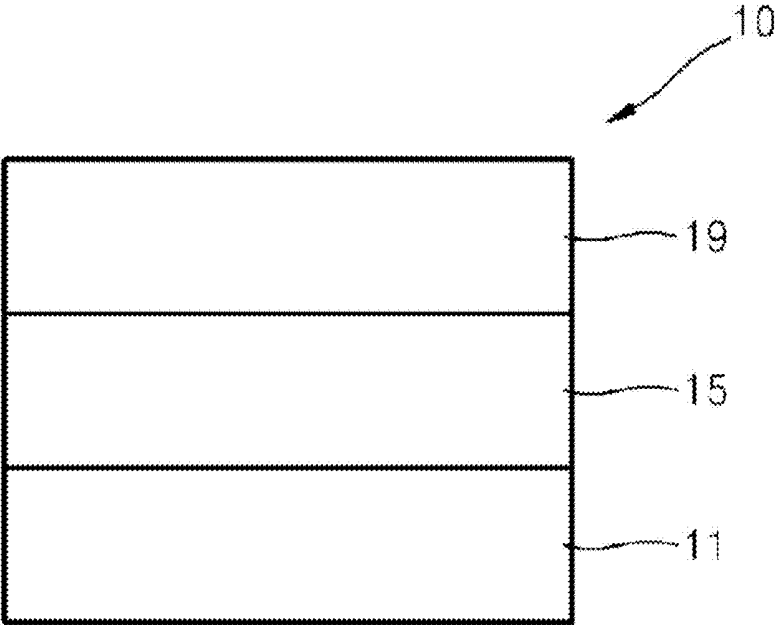
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(57) **ABSTRACT**
An organometallic compound represented by Formula 1:
$$M(L_1)(L_2)$$
 Formula 1
wherein, in Formula 1, M, L₁, and L₂ are the same as described in the specification.

14 Claims, 1 Drawing Sheet





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**ORGANOMETALLIC COMPOUND,
ORGANIC LIGHT EMITTING DEVICE, AND
COMPOSITION FOR DIAGNOSING
INCLUDING ORGANOMETALLIC
COMPOUND**

**CROSS-REFERENCE TO RELATED
APPLICATION**

This application claims priority to Korean Patent Application No. 10-2016-0015675, filed on Feb. 11, 2016 in the Korean Intellectual Property Office, and all the benefits accruing therefrom under 35 U.S.C. § 119, the content of which is incorporated herein in its entirety by reference.

BACKGROUND

1. Field

The present disclosure relates to an organometallic compound, an organic light-emitting device including the organometallic compound, and a composition for diagnosing including the organometallic compound.

2. Description of the Related Art

Organic light-emitting devices (OLEDs) are self-emission devices, which have wide viewing angles, exhibit excellent driving voltage and response speed characteristics, and produce full-color images.

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, wherein the organic layer 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 recombine in the emission layer to produce excitons. These excitons transit from an excited state to a ground state, thereby generating light.

Further, light-emitting compounds, e.g., phosphorescent emitting compounds, can also be used in monitoring, sensing, or detecting of biological materials including a variety of cells and proteins.

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

Provided are an organometallic compound, an organic light-emitting device including the organometallic compound, and a composition for diagnosing the organometallic compound.

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

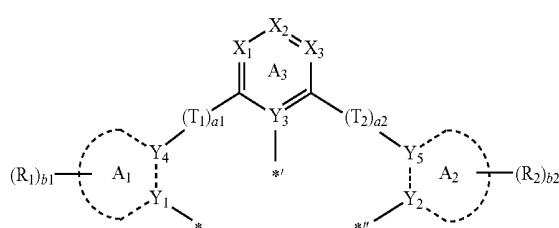
According an aspect of an embodiment, an organometallic compound is represented by Formula 1:

2

$M(L_1)(L_2)$

Formula 1

Formula 2



wherein, in Formulae 1 and 2,

M may be beryllium, magnesium, aluminum, calcium, titanium, manganese, cobalt, copper, zinc, gallium, germanium, zirconium, ruthenium, rhodium, palladium, silver, rhenium, gold, or platinum,

L_1 may be selected from tridentate ligands represented by Formula 2,

L_2 may be selected from monodentate organic ligands, * , *', and *'' in Formula 2 may each indicate a binding site to M in Formula 1,

Y_1 to Y_3 may each be nitrogen,

Y_4 and Y_5 may each be carbon,

Y_1 may be bound to Y_4 via a single or double bond, Y_2 may be bound to Y_5 via a single or double bond,

provided that one selected from a bond between Y_1 and M, a bond between Y_2 and M, and a bond between ligand L_2 and M may be a coordinate bond, while the rest are each a covalent bond,

a bond between Y_3 and M may be a coordinate bond,

ring A_1 may be a 5-membered ring including at least one nitrogen as a ring-forming atom,

ring A_2 may be a 6-membered ring including at least one nitrogen as a ring-forming atom,

X_1 may be N or C(R_3), X_2 may be N or C(R_4), X_3 may be N or C(R_5), at least two selected from R_3 to R_5 may optionally be bound to each other to form a substituted or unsubstituted C_5 - C_{30} carbocyclic group or a substituted or unsubstituted C_2 - C_{30} heterocyclic group,

T_1 may be a group selected from *—O—*', *—S—*', *—C(R_6)(R_7)—*', *—C(R_6)=*', *—C(R_6)—*', *—C(R_6)=C(R_7)—*', *—C(=O)—*', *—C(=S)—*', *—C≡C—*', *—N(R_6)—*', Si(R_6)(R_7)—*', and *—P(R_6)(R_7)—*', wherein * and *' in each of the foregoing groups independently indicate a binding site to a neighboring atom,

T_2 may be a group selected from *—O—*', *—S—*', *—C(R_6)(R_7)—*', *—C(R_6)=*', *—C(R_6)—*', *—C(R_6)=C(R_7)—*', *—C(=O)—*', *—C(=S)—*', *—C≡C—*', *—N(R_6)—*', *—Si(R_6)(R_7)—*', and *—P(R_6)(R_7)—*', wherein * and *' in each of the foregoing groups independently indicate a binding site to a neighboring atom,

R_6 and R_7 may optionally be bound to each other to form a substituted or unsubstituted C_5 - C_{30} carbocyclic group or a substituted or unsubstituted C_2 - C_{30} heterocyclic group,

a1 and a2 may be each independently an integer selected from 1 to 3,

R_1 to R_7 may be each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, —SF₅, 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 substituted or unsubstituted C_1 - C_{60} alkyl group, a substi-

tuted 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), —B(Q₆)(Q₇), and —P(=O)(Q₈)(Q₉),

b1 and b2 may be each independently an integer selected from 0 to 3, and when b1 is 2 or greater, groups R₁ may be identical to or different from each other, and when b2 is 2 or greater, groups R₂ may be identical to or different from each other,

two of the b1 number of groups R₁ may optionally be bound to each other to form a substituted or unsubstituted C₅-C₃₀ carbocyclic group or a substituted or unsubstituted C₂-C₃₀ heterocyclic group,

two of the b2 number of groups R₂ may optionally be bound to each other to form a substituted or unsubstituted C₅-C₃₀ carbocyclic group or a substituted or unsubstituted C₂-C₃₀ heterocyclic group,

at least one of substituents of the substituted C₅-C₃₀ carbocyclic group, substituted C₂-C₃₀ heterocyclic group, substituted C₁-C₆₀ alkyl group, substituted C₂-C₆₀ alkenyl group, substituted C₂-C₆₀ alkynyl group, substituted C₁-C₆₀ alkoxy group, substituted C₃-C₁₀ cycloalkyl group, substituted C₁-C₁₀ heterocycloalkyl group, substituted C₃-C₁₀ cycloalkenyl group, substituted C₁-C₁₀ heterocycloalkenyl group, substituted C₆-C₆₀ aryl group, substituted C₆-C₆₀ aryloxy group, substituted C₆-C₆₀ arylthio group, substituted C₁-C₆₀ heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from:

deuterium, —F, —Cl, —Br, —I, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, 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 deuterium, —F, —Cl, —Br, —I, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, 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), —B(Q₁₆)(Q₁₇), and —P(=O)(Q₁₈)(Q₁₉);

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 deuterium, —F, —Cl, —Br, —I, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, 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), —B(Q₂₆)(Q₂₇), and —P(=O)(Q₂₈)(Q₂₉); and

—N(Q₃₁)(Q₃₂), —Si(Q₃₃)(Q₃₄)(Q₃₅), —B(Q₃₆)(Q₃₇), and —P(=O)(Q₃₈)(Q₃₉),

wherein Q₁ to Q₉, Q₁₁ to Q₁₉, Q₂₁ to Q₂₉, and Q₃₁ to Q₃₉ may be each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid 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 aryl group substituted with at least one selected from a C₁-C₆₀ alkyl group and 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.

According to an aspect of another embodiment, an organic light-emitting device 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 described above.

In the emission layer, the organometallic compound may serve as a dopant.

According to an aspect of another embodiment, there is provided a composition for diagnosing that includes at least one organometallic compound represented by Formula 1.

BRIEF DESCRIPTION OF THE DRAWINGS

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

the FIGURE is a schematic cross-sectional view of an organic light-emitting device according to an embodiment.

DETAILED DESCRIPTION

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

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.

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.

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.

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

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

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.

“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.

An organometallic compound is represented by Formula 1:

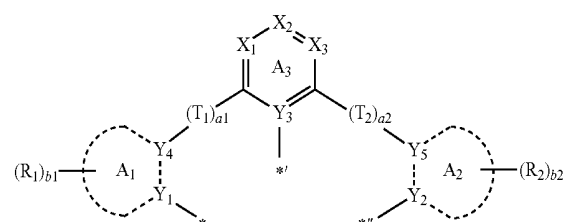


wherein, in Formula 1, M may be beryllium, magnesium, aluminum, calcium, titanium, manganese, cobalt, copper, zinc, gallium, germanium, zirconium, ruthenium, rhodium, palladium, silver, rhenium, gold, or platinum (Pt). For example, in Formula 1,

M may be platinum (Pt).

L_1 in Formula 1 may be selected from tridentate ligands represented by Formula 2, L_2 may be selected from monodentate organic ligands, and *, *, and * in Formula 2 each indicate a binding site to M in Formula 1.

Formula 2



wherein, in Formula 2, Y₁ to Y₃ may each be nitrogen (N), Y₄ and Y₅ may each be carbon (C), a bond between Y₁ and Y₄ may be a single bond or double bond, and a bond between Y₂ and Y₅ may be a single bond or a double bond.

In Formula 2,

a bond between Y₁ and M and a bond between ligand L_2 and M may each be a covalent bond, and a bond between Y₃ and M and a bond between Y₂ and M may each be a coordinate bond,

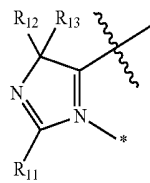
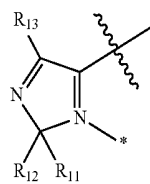
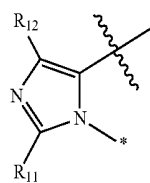
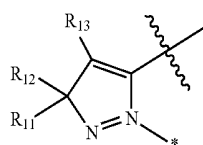
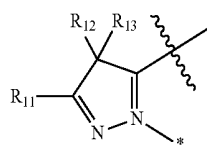
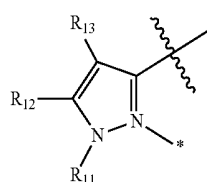
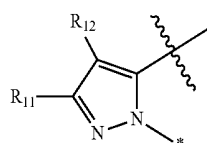
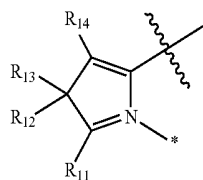
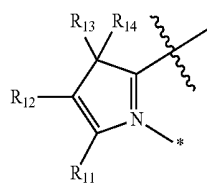
a bond between Y₁ and M and a bond between Y₂ and M may each be a covalent bond, and a bond between Y₃ and M and a bond between ligand L_2 and M may each be a coordinate bond, or

a bond between Y₂ and M and a bond between ligand L_2 and M may each be a covalent bond, and a bond between Y₁ and M and a bond between Y₃ and M may each be a coordinate bond.

Thus, the organometallic compound represented by Formula 1 may be electrically neutral, non-ionic compound having no charge.

Ring A₁ in Formula 2 may be a 5-membered ring including at least one nitrogen as a ring-forming atom, and ring A₂ may be a 6-membered ring including at least one nitrogen as a ring-forming atom.

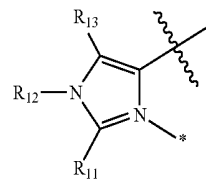
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Formula 3-3

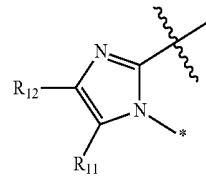
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Formula 3-4

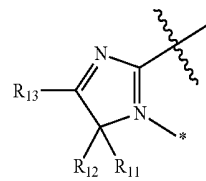
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Formula 3-5

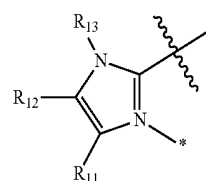
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Formula 3-6

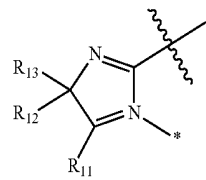
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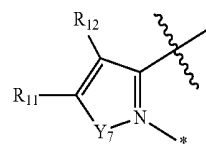
Formula 3-7

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Formula 3-8

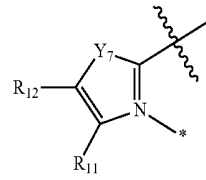
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Formula 3-9

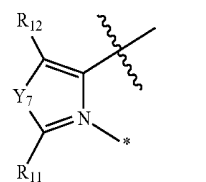
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Formula 3-10

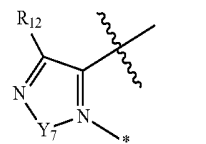
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Formula 3-11

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Formula 3-12

Formula 3-13

Formula 3-14

Formula 3-15

Formula 3-16

Formula 3-17

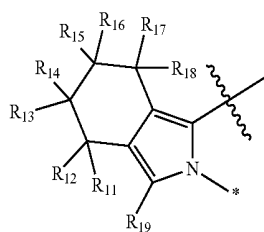
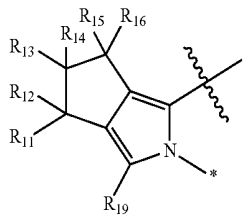
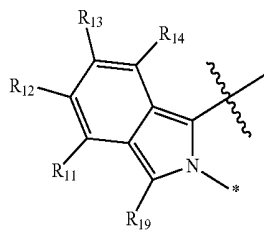
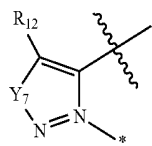
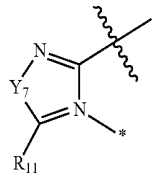
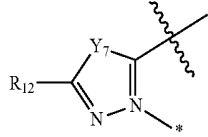
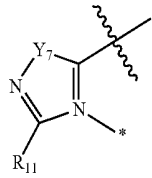
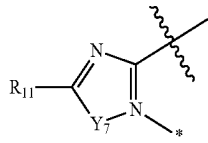
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Formula 3-19

Formula 3-20

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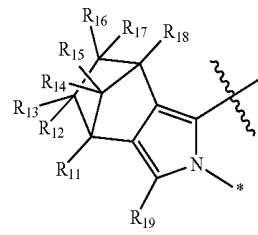


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Formula 3-21

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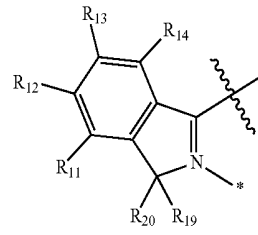


Formula 3-22

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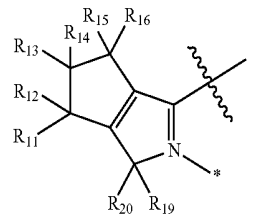
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Formula 3-24

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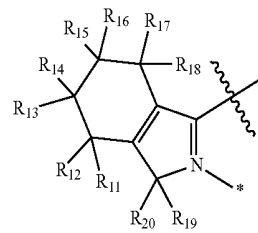


Formula 3-25

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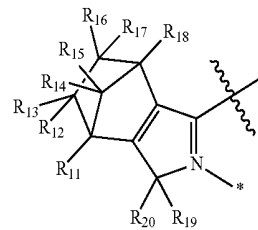
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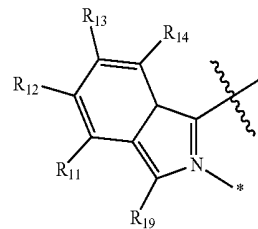
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Formula 3-33

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Formula 3-34

Formula 3-35

Formula 3-36

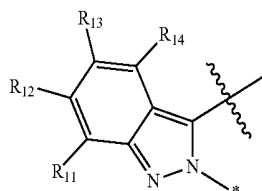
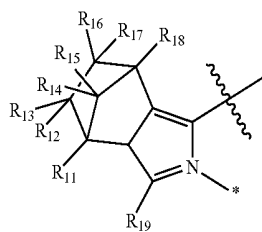
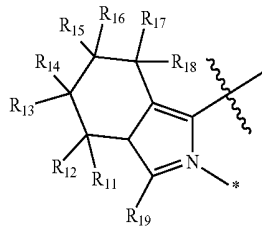
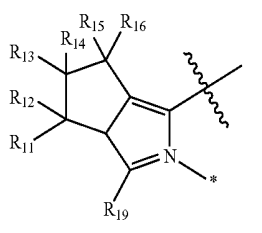
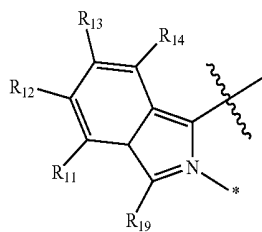
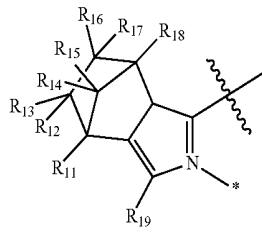
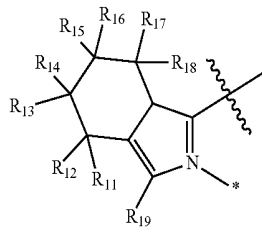
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Formula 3-38

Formula 3-39

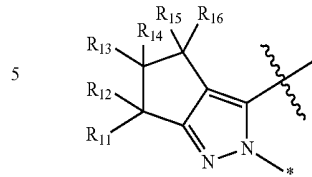
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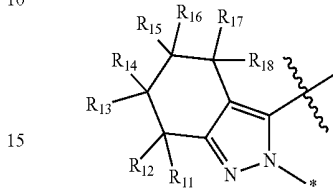


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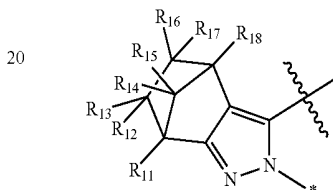
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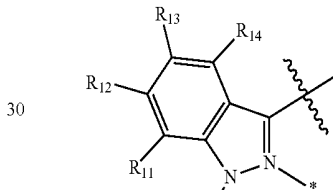
Formula 3-42



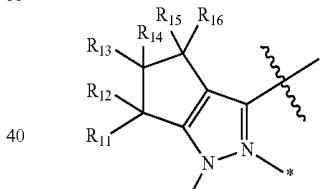
Formula 3-43



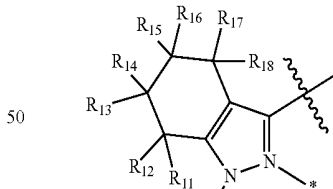
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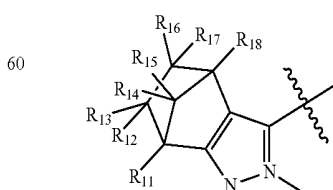
Formula 3-45



Formula 3-46



Formula 3-47



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Formula 3-48

Formula 3-49

Formula 3-50

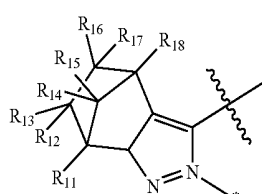
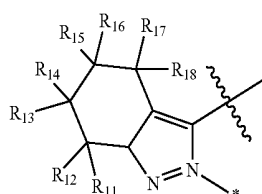
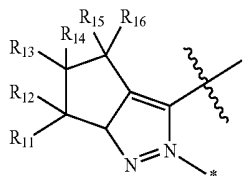
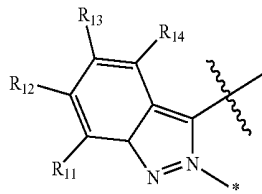
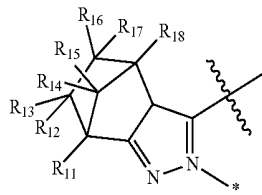
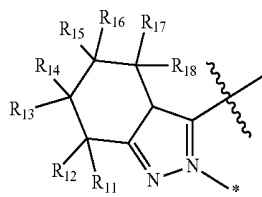
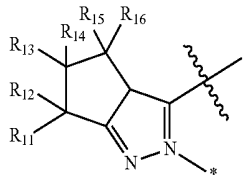
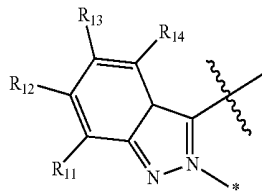
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Formula 3-52

Formula 3-53

Formula 3-54

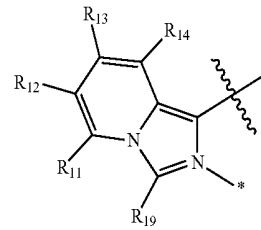
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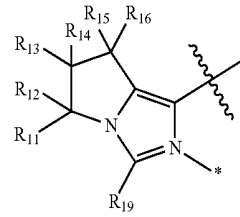
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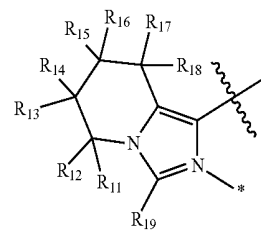
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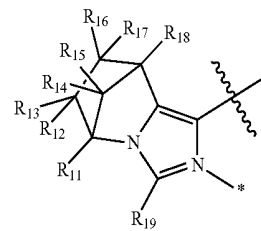
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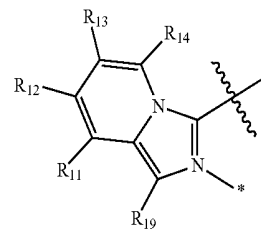
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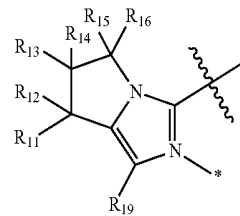
Formula 3-59

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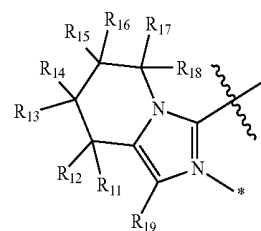
Formula 3-60

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Formula 3-61

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Formula 3-62

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Formula 3-63

Formula 3-64

Formula 3-65

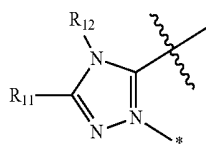
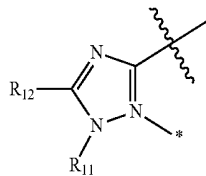
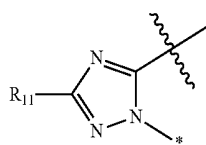
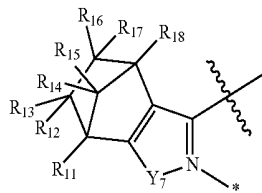
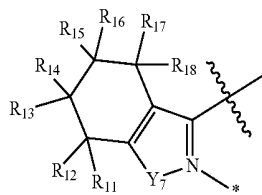
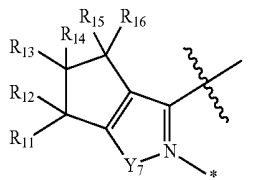
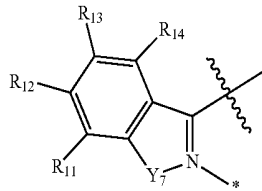
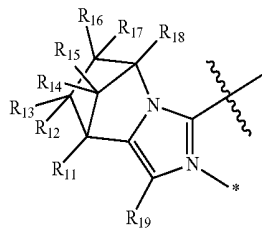
Formula 3-66

Formula 3-67

Formula 3-68

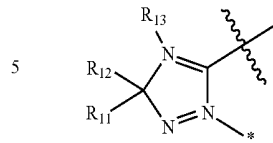
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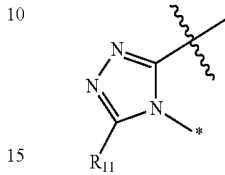


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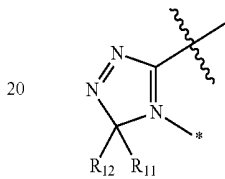
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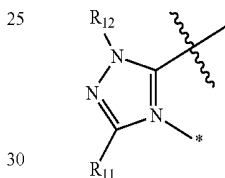
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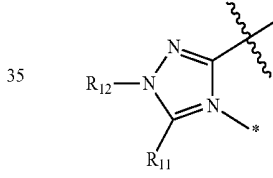
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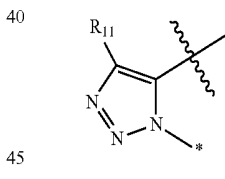
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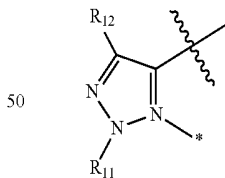
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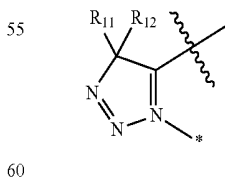
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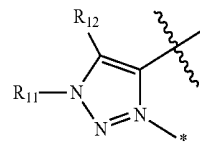
Formula 3-82



Formula 3-83



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Formula 3-84

Formula 3-85

Formula 3-86

Formula 3-87

Formula 3-88

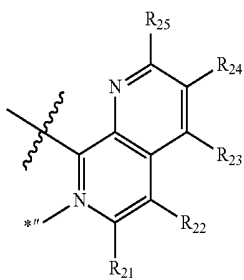
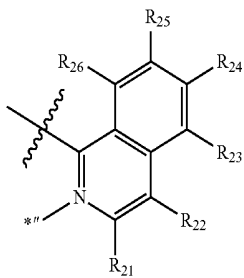
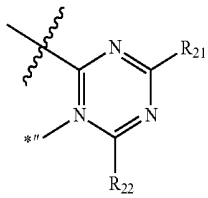
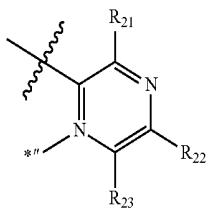
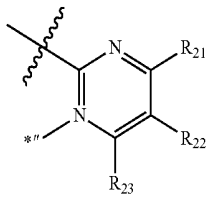
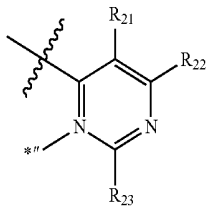
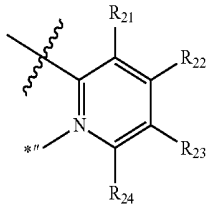
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Formula 3-90

Formula 3-91

Formula 3-92

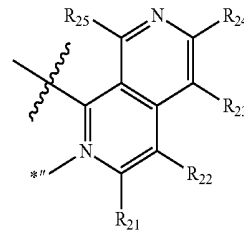
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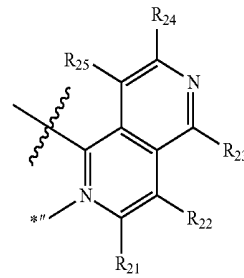
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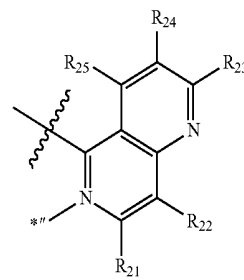
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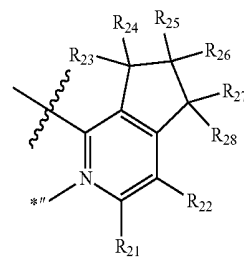
Formula 4-3

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Formula 4-4

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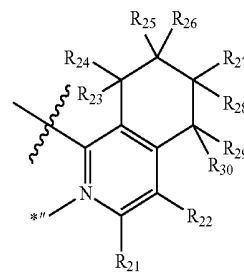


Formula 4-5

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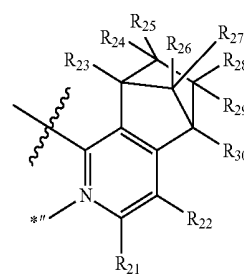
Formula 4-6

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Formula 4-7

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Formula 4-8

Formula 4-9

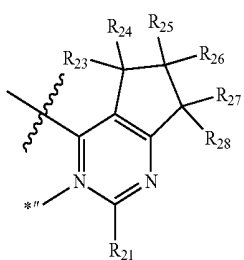
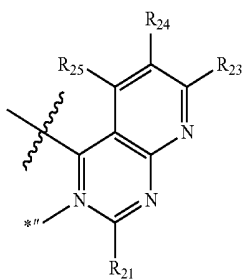
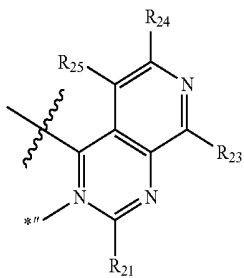
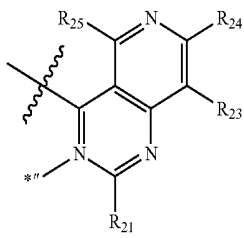
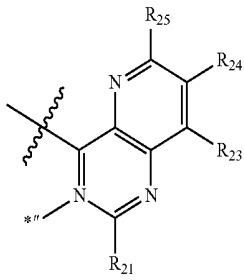
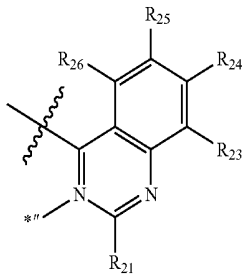
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Formula 4-11

Formula 4-12

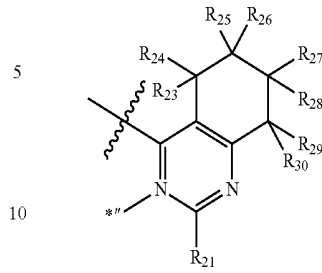
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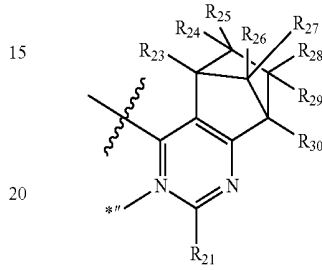


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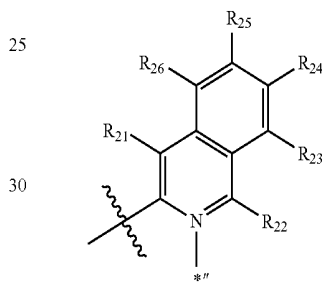
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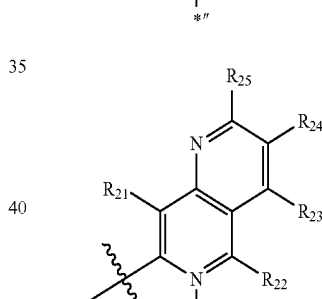
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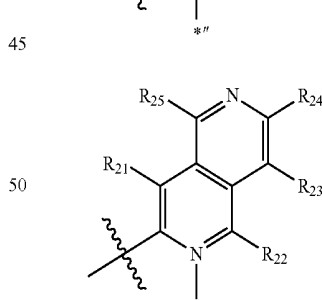
Formula 4-16



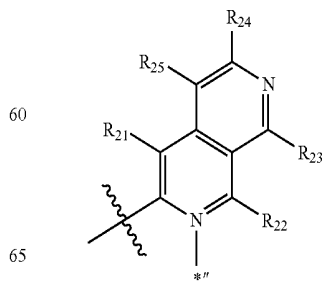
Formula 4-17



Formula 4-18



Formula 4-19



Formula 4-20

Formula 4-21

Formula 4-22

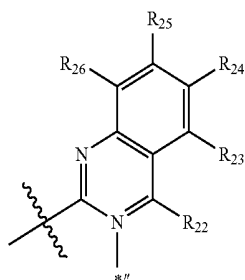
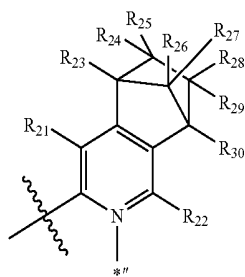
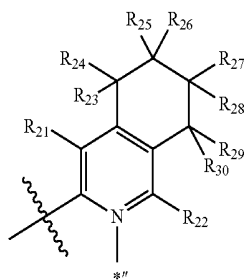
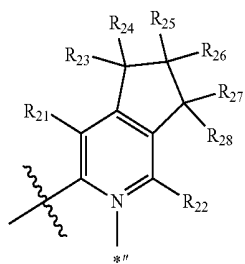
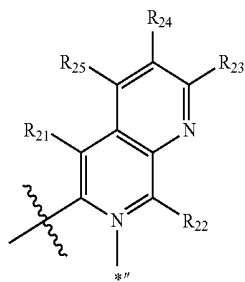
Formula 4-23

Formula 4-24

Formula 4-25

23

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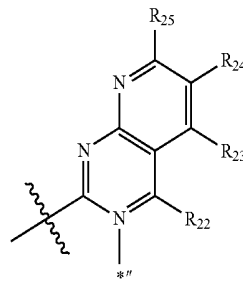


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Formula 4-26

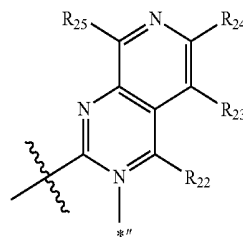
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Formula 4-27

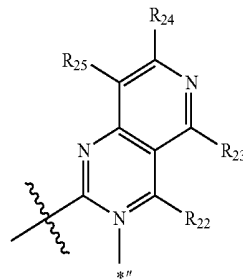
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Formula 4-28

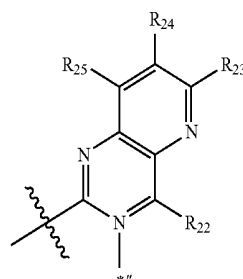
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Formula 4-29

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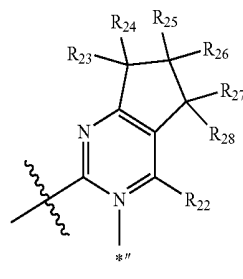


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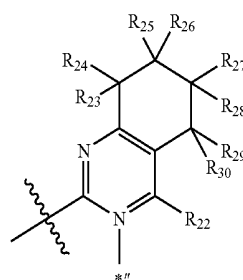
Formula 4-30

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Formula 4-31

Formula 4-32

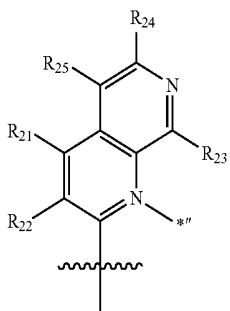
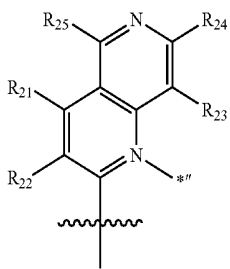
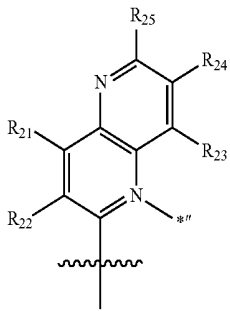
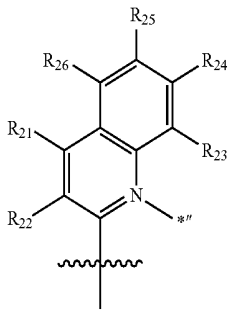
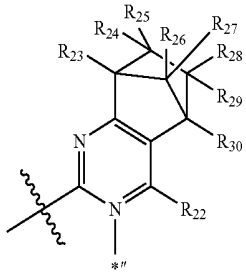
Formula 4-33

Formula 4-34

Formula 4-35

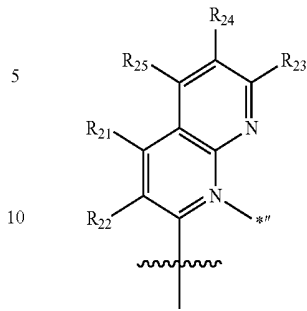
Formula 4-36

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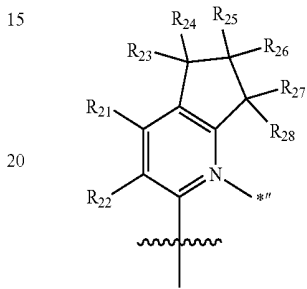


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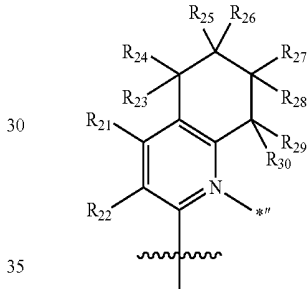
Formula 4-37



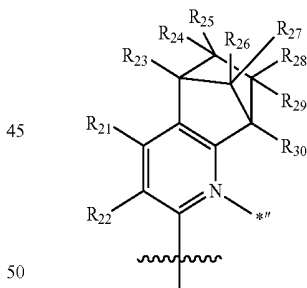
Formula 4-38



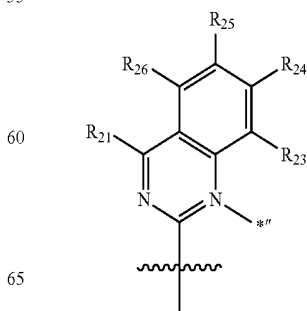
Formula 4-39



Formula 4-40



Formula 4-41



Formula 4-42

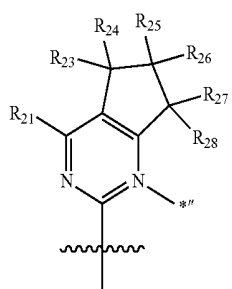
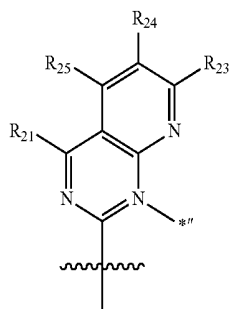
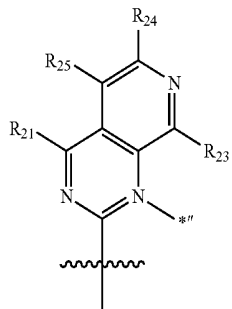
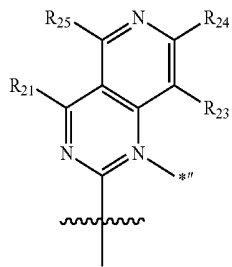
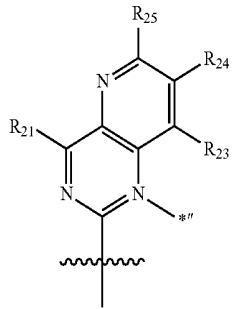
Formula 4-43

Formula 4-44

Formula 4-45

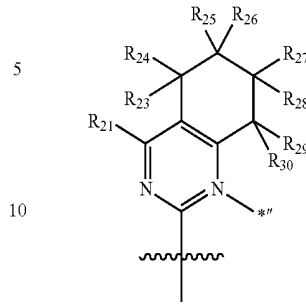
Formula 4-46

27
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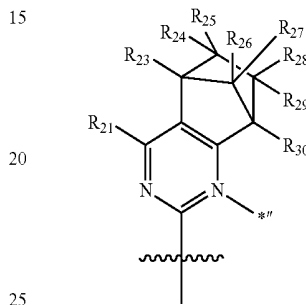


28
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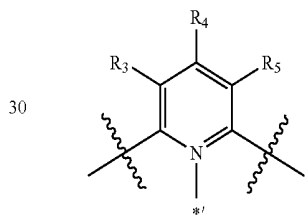
Formula 4-47



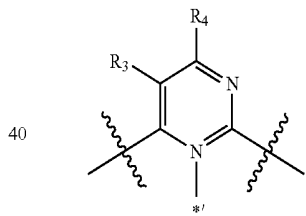
Formula 4-48



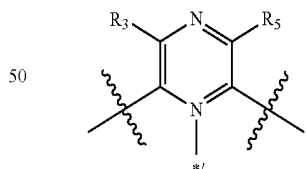
Formula 4-49



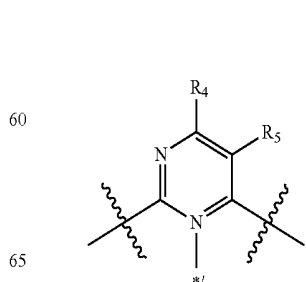
Formula 4-50



Formula 4-51



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Formula 4-52

Formula 4-53

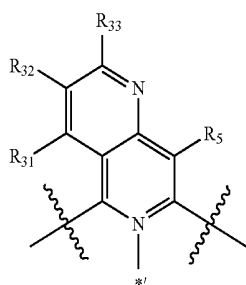
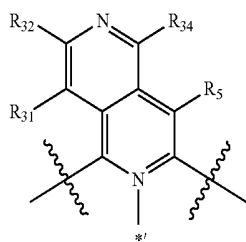
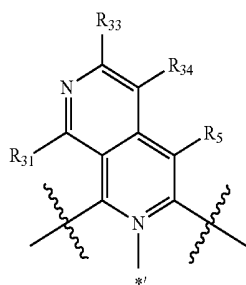
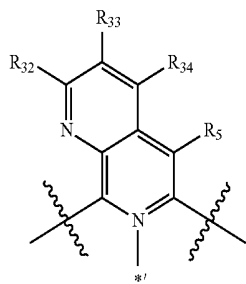
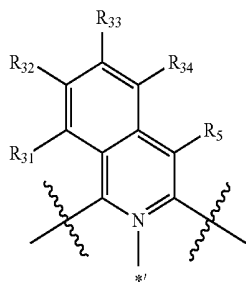
Formula 5-1

Formula 5-2

Formula 5-3

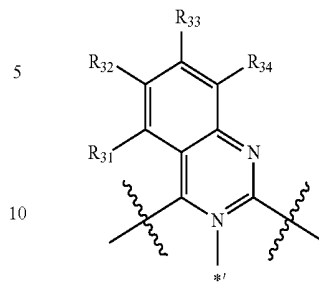
Formula 5-4

29
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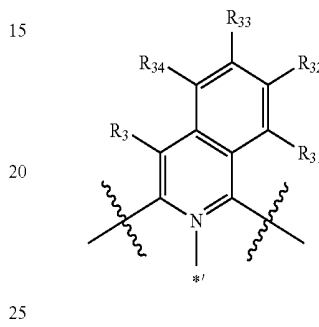


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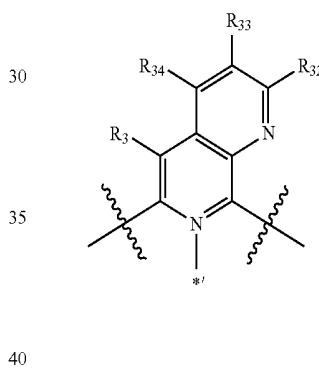
Formula 5-5



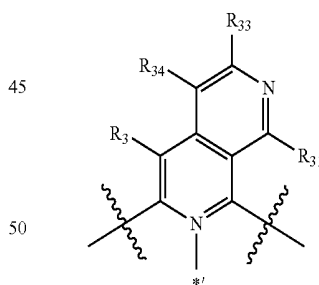
Formula 5-6



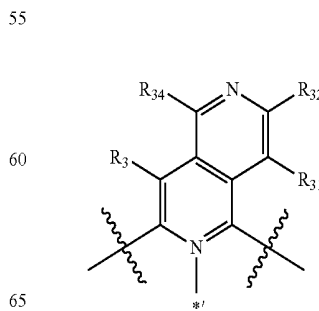
Formula 5-7



Formula 5-8



Formula 5-9



Formula 5-10

Formula 5-11

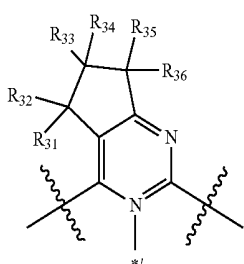
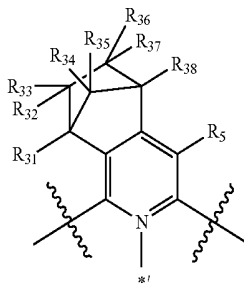
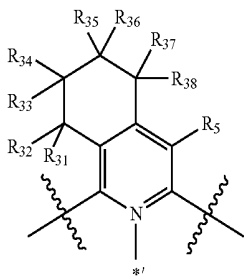
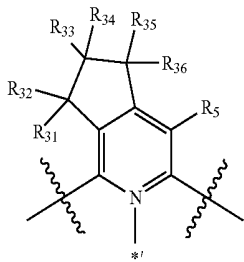
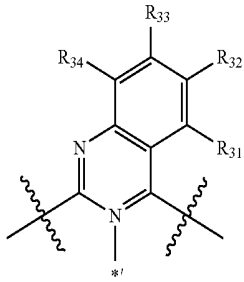
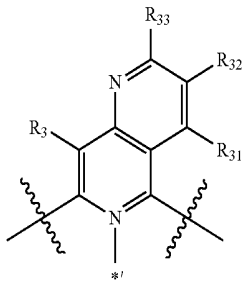
Formula 5-12

Formula 5-13

Formula 5-14

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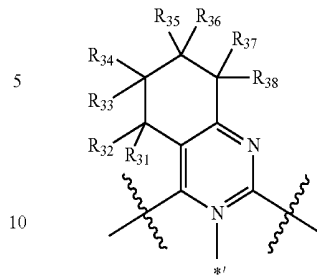
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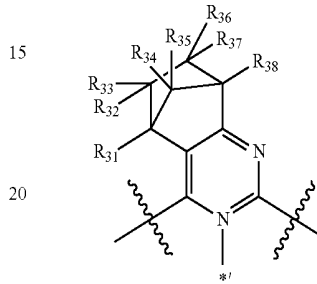
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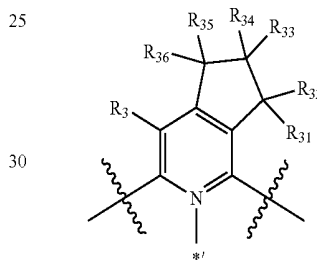
Formula 5-15



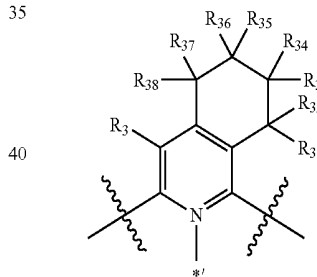
Formula 5-16



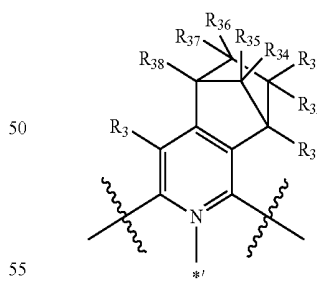
Formula 5-17



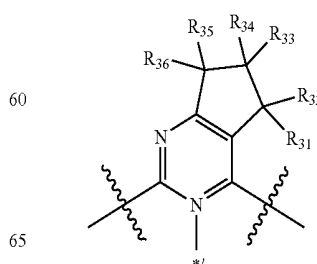
Formula 5-18



Formula 5-19



Formula 5-20



Formula 5-21

Formula 5-22

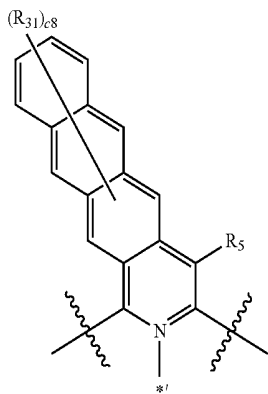
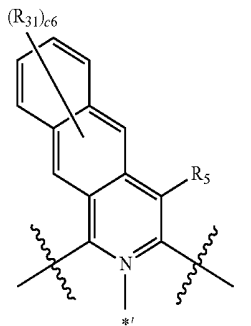
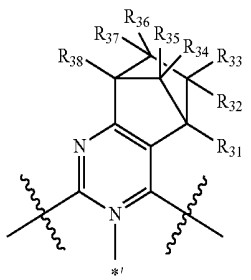
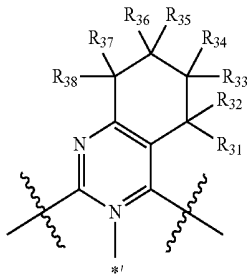
Formula 5-23

Formula 5-24

Formula 5-25

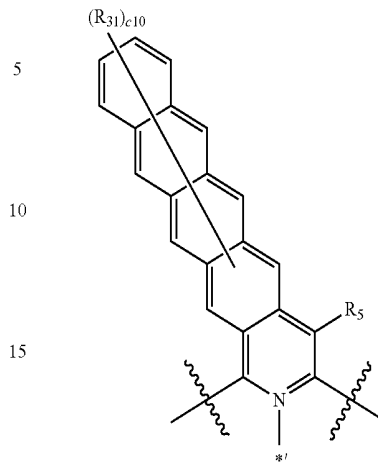
Formula 5-26

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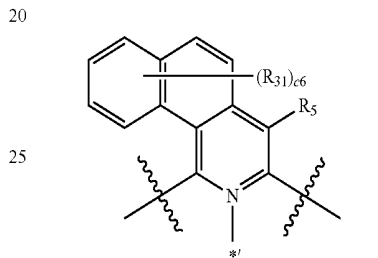


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Formula 5-27



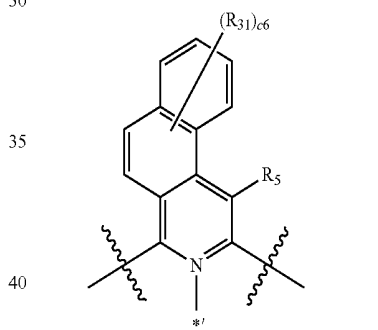
Formula 5-28



Formula 5-31

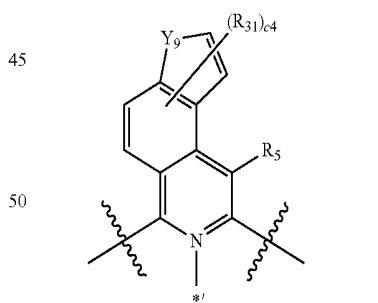
Formula 5-32

Formula 5-29

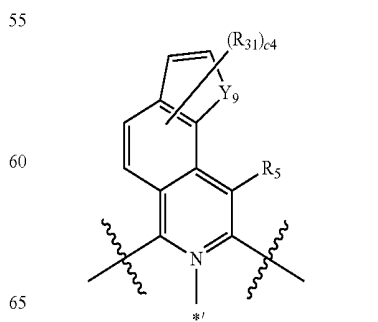


Formula 5-33

Formula 5-30

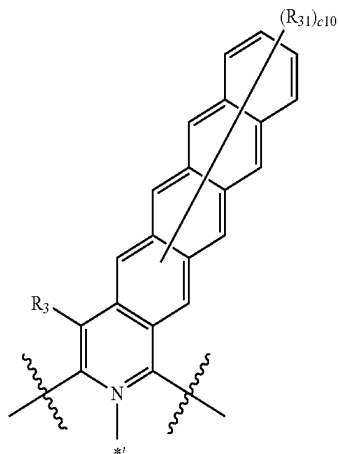
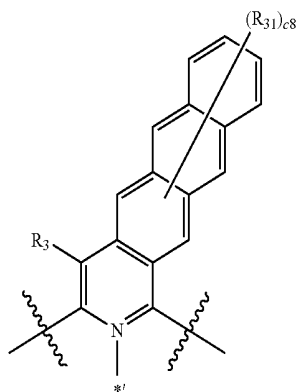
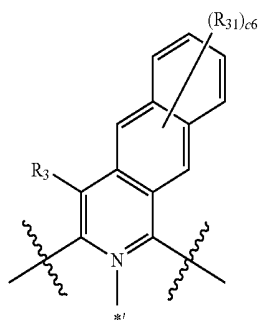
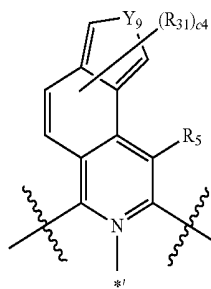


Formula 5-34



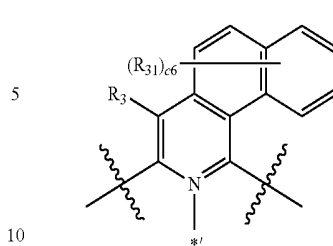
Formula 5-35

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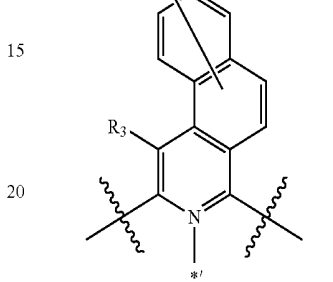
36
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Formula 5-36



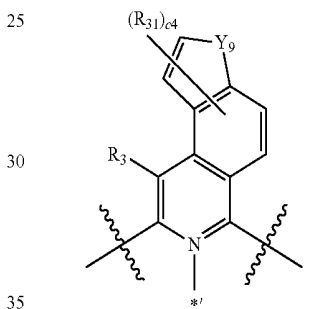
Formula 5-40

Formula 5-37



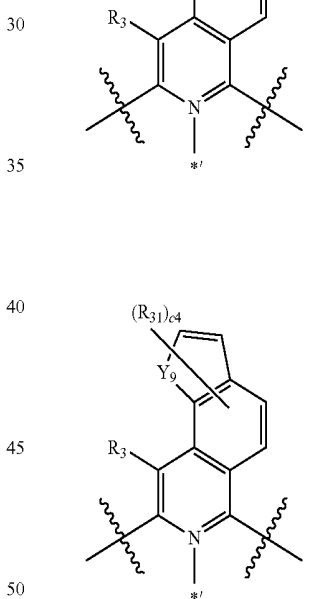
Formula 5-41

Formula 5-38



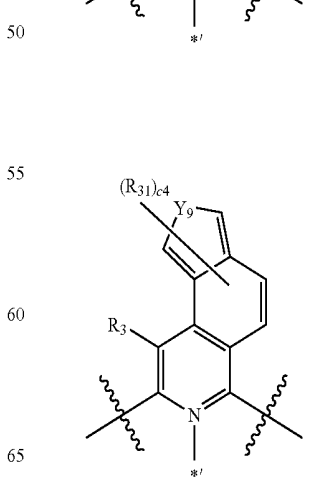
Formula 5-42

Formula 5-39



Formula 5-43

Formula 5-39

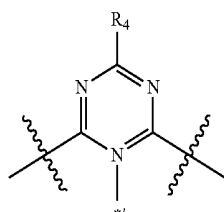
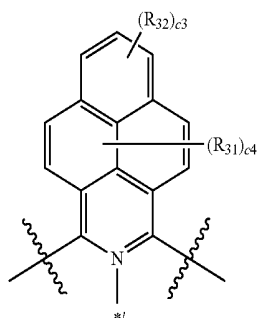
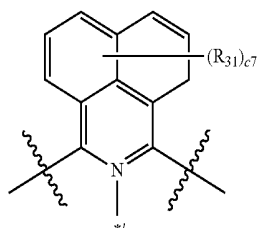
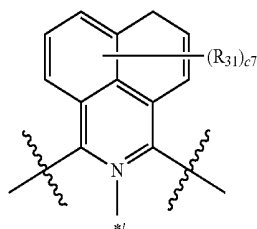


Formula 5-44

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wherein, in Formulae 3-1 to 3-25, 3-31 to 3-74, 3-81 to 3-92, 4-1 to 4-53, and 5-1 to 5-48,

Y_7 and Y_8 may be each independently O or S,

Y_9 may be O, S, or N(R_{39}),

R_3 to R_5 may be the same as those described herein,

R_{11} to R_{20} may be each independently the same as R_1 described herein,

R_{21} to R_{30} may be each independently the same as R_2 described herein,

R_{31} to R_{39} may be each independently the same as R_3 described herein,

c_3 may be an integer selected from 0 to 3,

c_4 may be an integer selected from 0 to 4,

c_6 may be an integer selected from 0 to 6,

c_7 may be an integer selected from 0 to 7,

c_8 may be an integer selected from 0 to 8,

c_{10} may be an integer selected from 0 to 10, and

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

R_3 to R_5 and R_{11} to R_{39} in Formulae 3-1 to 3-25, 3-31 to 3-74, 3-81 to 3-92, 4-1 to 4-53, and 5-1 to 5-48 are as provided herein.

R_1 to R_7 and R_{11} to R_{39} may be each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I,

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Formula 5-45

—SF₅, 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 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 non-aromatic condensed heteropolycyclic group, —N(Q₁)(Q₂), —Si(Q₃)(Q₄)(Q₅), —B(Q₆)(Q₇), and —P(=O)(Q₈)(Q₉).

Formula 5-47

According to an embodiment, R_1 to R_7 and R_{11} to R_{39} may be each independently selected from

hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic 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-C₂₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, 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 phosphoric acid group or a salt thereof, a C₁-C₁₀ alkyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group;

Formula 5-48

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

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

a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a

cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazoliny group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzoimidazolyl group, a benzofuranly group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranly 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, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, 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 cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazoliny group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzoimidazolyl group, a benzofuranly group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranly group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group; and

—N(Q₁)(Q₂), —Si(Q₃)(Q₄)(Q₅), —B(Q₆)(Q₇), and —P(=O)(Q₈)(Q₉),

wherein Q₁ to Q₉ may be each independently selected from

—CH₃, —CD₃, —CD₂H, —CDH₂, —CH₂CH₃, —CH₂CD₃, —CH₂CD₂H, —CH₂CDH₂, —CHDCH₃, —CHDCH₂H, —CHDCH₂H, —CHDCH₃, —CD₂CD₃, —CD₂CD₂H, and —CD₂CDH₂;

an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, a C₁-C₁₀ alkyl group, and a phenyl group.

In some embodiments, R₁ to R₇ and R₁₁ to R₃₉ may be each independently selected from

hydrogen, deuterium, —F, a cyano group, a nitro group, —SF₅, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an iso-hexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an iso-heptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an iso-octyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an iso-nonyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an iso-decyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a dibenzofuranly group, and a dibenzothiophenyl group;

a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an iso-hexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an iso-heptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an iso-octyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an iso-nonyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an iso-decyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a dibenzofuranly group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, —F, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, a cyano group, a nitro group, a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a dibenzofuranly group, and a dibenzothiophenyl group; and

—N(Q₁)(Q₂), —Si(Q₃)(Q₄)(Q₅), —B(Q₆)(Q₇), and —P(=O)(Q₈)(Q₉),

wherein Q₁ to Q₉ may be each independently selected from

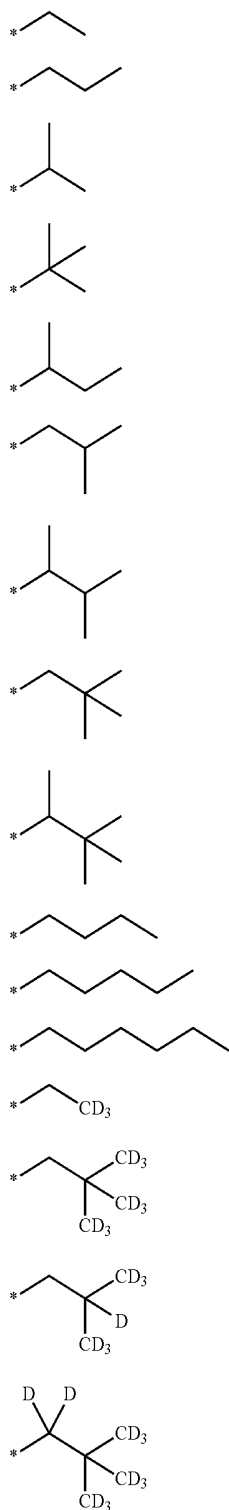
—CH₃, —CD₃, —CD₂H, —CDH₂, —CH₂CH₃, —CH₂CD₃, —CH₂CD₂H, —CH₂CDH₂, —CHDCH₃, —CHDCH₂H, —CHDCH₂H, —CHDCH₃, —CD₂CD₃, —CD₂CD₂H, and —CD₂CDH₂;

an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group,

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each substituted with at least one selected from deuterium, a C₁-C₁₀ alkyl group, and a phenyl group.

In some embodiments, R₁ to R₇ and R₁₁ to R₃₉ may be each independently selected from hydrogen, deuterium, —F, a cyano group, a nitro group, —SF₅, —CH₃, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, groups represented by Formulae 9-1 to 9-19, groups represented by Formulae 10-1 to 10-38, and —Si(Q₃)(Q₄)(Q₅), but embodiments are not limited thereto:



Formula 9-1

Formula 9-2

Formula 9-3

Formula 9-4

Formula 9-5

Formula 9-6

Formula 9-7

Formula 9-8

Formula 9-9

Formula 9-10

Formula 9-11

Formula 9-12

Formula 9-13

Formula 9-14

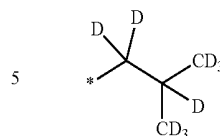
Formula 9-15

Formula 9-16

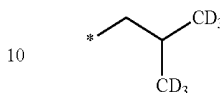
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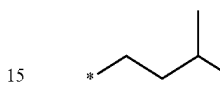
Formula 9-17



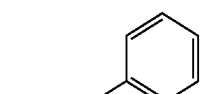
Formula 9-18



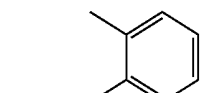
Formula 9-19



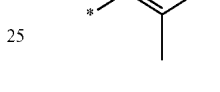
Formula 10-1



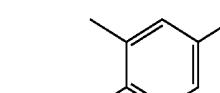
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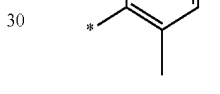
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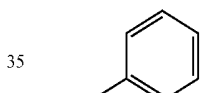
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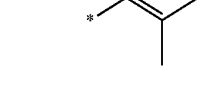
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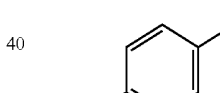
Formula 10-6



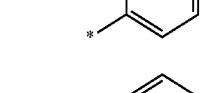
Formula 10-7



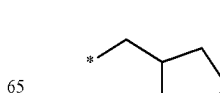
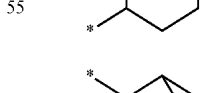
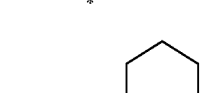
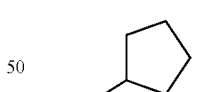
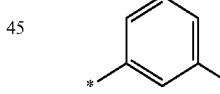
Formula 10-8



Formula 10-9

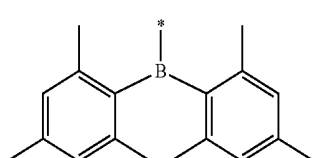
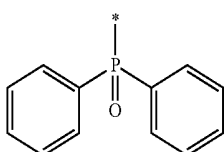
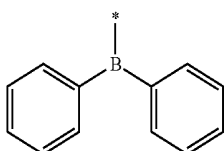
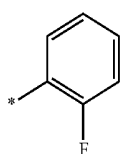
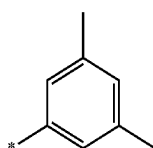
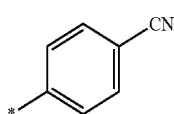
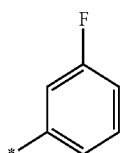
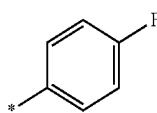
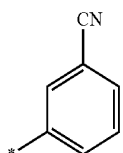
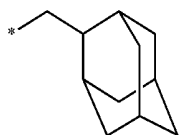
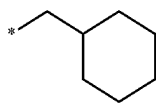


Formula 10-10



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Formula 10-11

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Formula 10-12

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Formula 10-13

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Formula 10-14

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Formula 10-15

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Formula 10-16

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Formula 10-17

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Formula 10-18

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Formula 10-19

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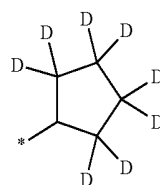
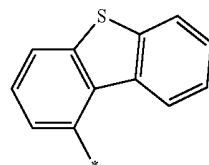
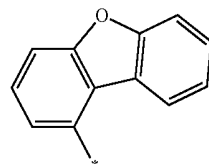
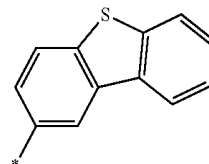
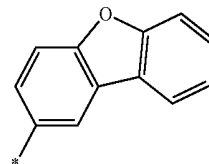
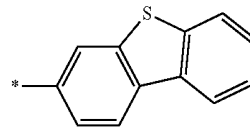
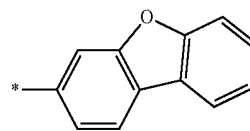
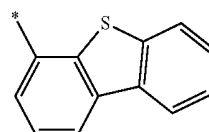
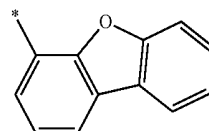
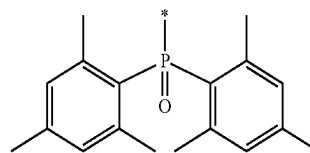
Formula 10-20

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Formula 10-21

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Formula 10-22

Formula 10-23

Formula 10-24

Formula 10-25

Formula 10-26

Formula 10-27

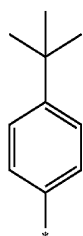
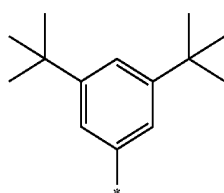
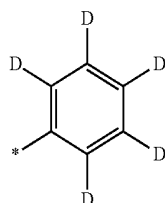
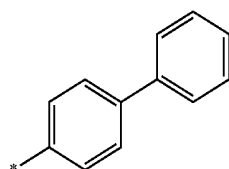
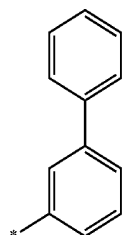
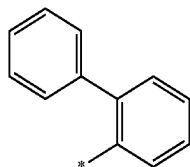
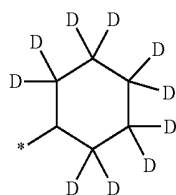
Formula 10-28

Formula 10-29

Formula 10-30

Formula 10-31

-continued



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

In Formula 2, b1 and b2 may be each independently an integer selected from 0 to 3, and when b1 is 2 or greater, groups R₁ may be identical to or different from each other, and when b2 is 2 or greater, groups R₂ may be identical to or different from each other.

In Formula 2, two of the b1 number of groups R₁ may optionally be bound to each other to form a substituted or

Formula 10-32

unsubstituted C₅-C₃₀ carbocyclic group or a substituted or unsubstituted C₂-C₃₀ heterocyclic group (e.g., a substituted or unsubstituted cyclopentane group, a substituted or unsubstituted cyclohexane group, a substituted or unsubstituted adamantane group, a substituted or unsubstituted benzene group, a substituted or unsubstituted pyridine group, a substituted or unsubstituted pyrimidine group, a substituted or unsubstituted pyrazine group, a substituted or unsubstituted pyridazine group, or a substituted or unsubstituted naphthalene group).

Formula 10-33

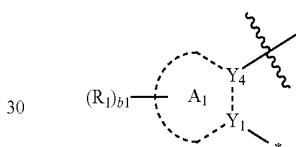
In Formula 2, two of the b2 number of groups R₂ may optionally be bound to each other to form a substituted or unsubstituted C₅-C₃₀ carbocyclic group or a substituted or unsubstituted C₂-C₃₀ heterocyclic group (e.g., a substituted or unsubstituted cyclopentane group, a substituted or unsubstituted cyclohexane group, a substituted or unsubstituted adamantane group, a substituted or unsubstituted benzene group, a substituted or unsubstituted pyridine group, a substituted or unsubstituted pyrimidine group, a substituted or unsubstituted pyrazine group, a substituted or unsubstituted pyridazine group, or a substituted or unsubstituted naphthalene group).

Formula 10-34

Formula 10-35

According to an embodiment, a moiety represented by

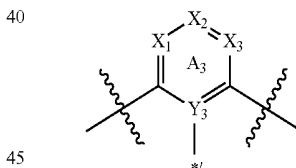
Formula 10-36



in Formula 2 may be represented by one of Formulae 3-1, 3-5, 3-9, 3-13, 3-31 to 3-34, 3-47 to 3-50, 3-81, 3-85, and 3-89, but embodiments are not limited thereto.

In various embodiments, a moiety represented by

Formula 10-37



Formula 10-38

In Formula 2 may be represented by one of Formulae 5-1 to 5-28, 5-29, and 5-45, but embodiments are not limited thereto.

In some embodiments, in Formula 2,

T₂ may be a group selected from *—O—*, *—S—*, *—C(R₆)(R₇)—*, *—N(R₆)—*, and *—Si(R₆)(R₇)—*, wherein * and *' in each of the foregoing groups independently indicate a binding site to a neighboring atom, and

R₆ and R₇ may optionally be bound to each other via a first linking group,

wherein the first linking group may be selected from a single bond, a C₁-C₃ alkylene group, and a C₂-C₃ alkenylene group;

a C₁-C₃ alkylene group and a C₂-C₃ alkenylene group, each substituted with at least one selected from deuterium, a cyano group, C₁-C₁₀ alkyl group, C₁-C₁₀ alkoxy group, a phenyl group, and a biphenyl group, and

a₂ may be 1.

In some embodiments, in Formula 2,

T₁ may be a single bond,

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T_2 may be a group selected from $*-O-*$, $*-S-*$, $*-C(R_6)(R_7)-*$, $*-N(R_6)-*$, and $*-Si(R_6)(R_7)-*$, wherein $*$ and $*'$ in each of the foregoing groups independently indicate a binding site to a neighboring atom,

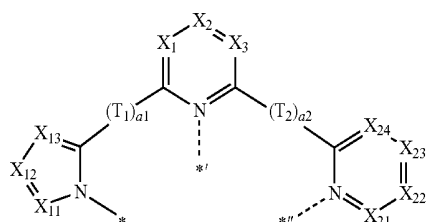
R_6 to R_7 may be each independently selected from hydrogen, deuterium, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, and a biphenyl group; and a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, and a biphenyl group, each substituted with at least one selected from deuterium, a cyano group, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, and a phenyl group,

wherein R_6 and R_7 may optionally be bound to each other via a single bond, and

a1 may be 1.

According to some embodiments, L_1 in Formula 1 may be selected from ligands represented by Formula 2-1:

Formula 2-1



wherein, in Formula 2-1,

T_1 , T_2 , a1, a2, X_1 to X_3 , $*$, $*'$, and $*''$ are the same as those described herein,

X_{11} may be C or N(R_{11a}), X_{12} may be C or N(R_{12a}), X_{13} may be C or N(R_{13a}), X_{21} may be C or N(R_{21a}), X_{22} may be C or N(R_{22a}), X_{23} may be C or N(R_{23a}), X_{24} may be C or N(R_{24a}),

R_{11a} to R_{13a} are each the same as described herein in connection with R_1 ,

R_{21a} to R_{24a} are each the same as described herein in connection with R_2 ,

at least two of R_{11a} to R_{13a} may optionally be bound to each other to form a substituted or unsubstituted C_5-C_{30} carbocyclic group or a substituted or unsubstituted C_2-C_{30} heterocyclic group (e.g., a substituted or unsubstituted cyclopentane group, a substituted or unsubstituted cyclohexane group, a substituted or unsubstituted adamantane group, a substituted or unsubstituted benzene group, a substituted or unsubstituted pyridine group, a substituted or unsubstituted pyrimidine group, a substituted or unsubstituted pyrazine group, a substituted or unsubstituted pyridazine group, or a substituted or unsubstituted naphthalene group), and

at least two of R_{21a} to R_{24a} may optionally be bound to each other to form a substituted or unsubstituted C_5-C_{30} carbocyclic group or a substituted or unsubstituted C_2-C_{30} heterocyclic group (e.g., a substituted or unsubstituted cyclopentane group, a substituted or unsubstituted cyclohexane group, a substituted or unsubstituted adamantane group, a substituted or unsubstituted benzene group, a substituted or unsubstituted pyridine group, a substituted or unsubstituted pyrimidine group, a substituted or unsubstituted pyrazine group, a substituted or unsubstituted pyridazine group, or a substituted or unsubstituted naphthalene group).

According to an embodiment, in Formula 2-1, a) two of R_{11a} to R_{13a} or b) two of R_{21a} to R_{24a} may optionally be bound to each other to form one selected from

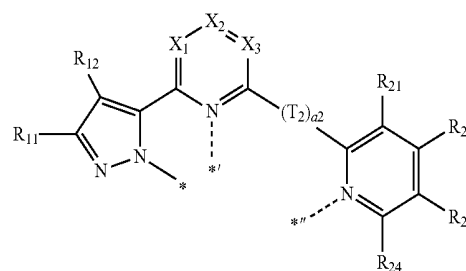
48

a cyclopentane group, a cyclohexane group, an adamantane group, a norbornane group, a benzene group, a pyridine group, a pyrimidine group, a naphthalene group, a pyrene group, and a chrysene group; and

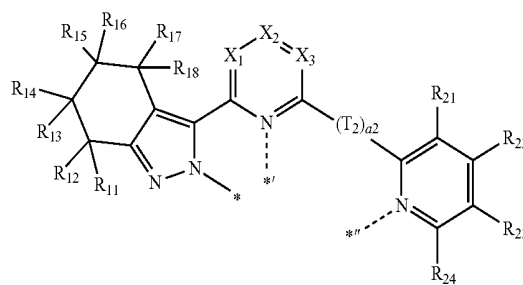
a cyclopentane group, a cyclohexane group, an adamantane group, a norbornane group, a benzene group, a pyridine group, a pyrimidine group, a naphthalene group, a pyrene group, and a chrysene group, each substituted with at least one selected from deuterium, $-F$, $-CD_3$, $-CD_2H$, $-CDH_2$, $-CF_3$, $-CF_2H$, $-CFH_2$, a cyano group, a nitro group, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, but embodiments are not limited thereto.

According to some embodiments, L_1 in Formula 1 may be selected from ligands represented by one of Formulae 2A to 2C:

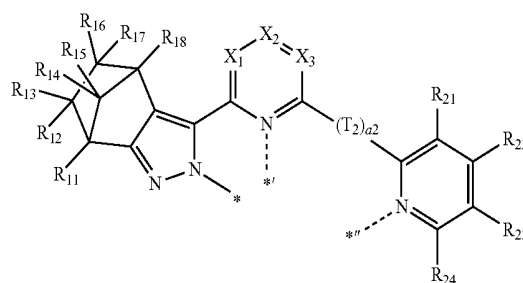
Formula 2A



Formula 2B



Formula 2C



wherein, in Formulae 2A to 2C,

T_2 , a2, X_1 to X_3 , $*$, $*'$, and $*''$ are the same as those described herein,

R_{11} to R_{18} are each the same as described herein in connection with R_1 ,

R_{21} to R_{24} are each the same as described herein in connection with R_2 , and at least two of R_{21} to R_{24} may optionally be bound to each other to form a substituted or

unsubstituted C₅-C₃₀ carbocyclic group or a substituted or unsubstituted C₂-C₃₀ heterocyclic group.

L₂ in Formula 1 may be selected from ligands represented by Formula 6-1:



wherein, in Formula 6-1,

T₃ may be a group selected from a single bond, *—O—*, *—S—*, *—C(R₆₂)(R₆₃)—*, *—C(R₆₂)=*, *—C(R₆₂)—*, *—C(R₆₂)=C(R₆₃)—*, *—C(=O)—*, *—C(=S)—*, *—C≡C—*, and *—N(R₆₂)—*, wherein * and * in each of the foregoing groups independently indicate a binding site to a neighboring atom,

a₃ may be an integer selected from 1 to 5,

R₆₁ may be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, —SF₅, 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 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), —B(Q₆)(Q₇), —P(=O)(Q₈)(Q₉), and P(Q₄₁)(Q₄₂)(Q₄₃),

wherein Q₁ to Q₉ and Q₄₁ to Q₄₃ may be each independently selected from

—CH₃, —CD₃, —CD₂H, —CDH₂, —CH₂CH₃, —CH₂CD₃, —CH₂CD₂H, —CH₂CDH₂, —CHDCH₃, —CHDCH₂H, —CHDCHD₂H, —CHDCHD₂H, —CHDCHD₃, —CD₂CD₃, —CD₂CD₂H, and —CD₂CDH₂;

an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, a C₁-C₁₀ alkyl group, and a phenyl group,

R₆₂ to R₆₃ may be each independently selected from

hydrogen, deuterium, —F, a cyano group, a nitro group, —SF₅, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an iso-hexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an iso-heptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an iso-octyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an iso-nonyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an iso-decyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a cyclopentyl group, a cyclohexyl group, a cyclo-

heptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an iso-hexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an iso-heptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an iso-octyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an iso-nonyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an iso-decyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, —F, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, a cyano group, a nitro group, a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group,

R₆₂ and R₆₃ may optionally be bound to each other to form a substituted or unsubstituted C₅-C₃₀ carbocyclic group or a substituted or unsubstituted C₂-C₃₀ heterocyclic group, and

* in Formula 1 indicates a binding site to M.

In some embodiments, R₆₁ may be selected from

hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid 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-C₂₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, 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, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group; a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a

pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzoimidazolyl group, a benzofuranlyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranlyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group;

a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzoimidazolyl group, a benzofuranlyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranlyl 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, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, 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 C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzoimidazolyl group, a benzofuranlyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranlyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group; and

—N(Q₁)(Q₂), —Si(Q₃)(Q₄)(Q₅), —B(Q₆)(Q₇), —P(=O)(Q₈)(Q₉), and P(Q₄₁)(Q₄₂)(Q₄₃),

wherein Q₁ to Q₉ and Q₄₁ to Q₄₃ may be each independently selected from

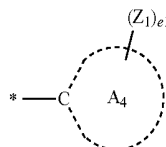
—CH₃, —CD₃, —CD₂H, —CDH₂, —CH₂CH₃, —CH₂CD₃, —CH₂CD₂H, —CH₂CDH₂, —CHDC₃, —CHDCD₂H, —CHDCDH₂, —CHDCD₃, —CD₂CD₃, —CD₂CD₂H, and —CD₂CDH₂;

an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

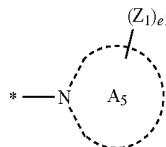
an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, a C₁-C₁₀ alkyl group, and a phenyl group, but embodiments are not limited thereto.

According to an embodiment, L₂ in Formula 1 may be selected from ligands represented by one of Formulae 12-2 to 12-5, but embodiments are not limited thereto:

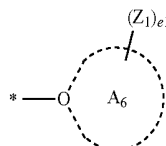
Formula 12-2



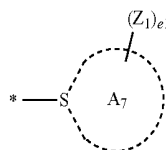
Formula 12-3



Formula 12-4



Formula 12-5



wherein, in Formulae 12-2 to 12-5,

ring A₄ may be selected from a cyclopentene ring, a cyclohexene ring, a cycloheptene ring, a benzene ring, an indene ring, a naphthalene ring, an azulene ring, a heptalene ring, an indacene ring, acenaphthylene ring, a fluorene ring, a spiro-bifluorene ring, a benzofluorene ring, a dibenzofluorene ring, a phenalene ring, a phenanthrene ring, an anthracene ring, a fluoranthene ring, a triphenylene ring, a pyrene ring, a chrysenene ring, a naphthacene ring, a picene ring, a perylene ring, a pentacene ring, a hexacene ring, a pentaphene ring, a rubicene ring, a coronene ring, an ovalene ring, a pyrrole ring, a thiophene ring, a furan ring, an imidazole ring, a pyrazole ring, a thiazole ring, an isothiazole ring, an oxazole ring, an isoxazole ring, a pyridine ring, a pyrazine ring, a pyrimidine ring, a pyridazine ring, an iso-indole ring, an indole ring, indazole ring, a purine ring, a quinoline ring, an isoquinoline ring, a benzoquinoline ring, a quinoxaline

ring, a quinazoline ring, a cinnoline ring, a naphthyridine ring, a carbazole ring, a phenanthroline ring, a benzimidazole ring, a benzofuran ring, a benzothiophene ring, a benzothiazole ring, an iso-benzothiazole ring, a benzoxazole ring, an isobenzoxazole ring, a triazole ring, a tetrazole ring, an oxadiazole ring, a thiadiazole ring, a triazine ring, a dibenzofuran ring, a dibenzothiophene ring, a benzocarbazole ring, a dibenzocarbazole ring, an imidazopyridine ring, and an imidazopyrimidine ring,

ring A₅ may be selected from a pyrrole ring, an imidazole ring, a pyrazole ring, a thiazole ring, an isothiazole ring, an oxazole ring, an isoxazole ring, a pyridine ring, a pyrazine ring, a pyrimidine ring, a pyridazine ring, an iso-indole ring, an indole ring, an indazole ring, a purine ring, a quinoline ring, an isoquinoline ring, a benzoquinoline ring, a quinoxaline ring, a quinazoline ring, a cinnoline ring, a naphthyridine ring, a carbazole ring, a phenanthroline ring, a benzimidazole ring, a benzofuran ring, a benzothiazole ring, an iso-benzothiazole ring, a benzoxazole ring, an isobenzoxazole ring, a triazole ring, a tetrazole ring, an oxadiazole ring, a thiadiazole ring, a triazine ring, a benzocarbazole ring, a dibenzocarbazole ring, an imidazopyridine ring, and an imidazopyrimidine ring,

ring A₆ may be selected from a furan ring, an oxazole ring, an isoxazole ring, a benzofuran ring, a benzoxazole ring, an isobenzoxazole ring, an oxadiazole ring, and a dibenzofuran ring,

ring A₇ may be selected from a thiophene ring, a thiazole ring, an isothiazole ring, a benzothiophene ring, a benzothiazole ring, an iso-benzothiazole ring, a thiadiazole ring, and a dibenzothiophene ring,

Z₁ may be each independently selected from

hydrogen, deuterium, —F, a cyano group, a nitro group, —SF₅, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an iso-hexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an iso-heptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an iso-octyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an iso-nonyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an iso-decyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an iso-hexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an iso-heptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an iso-octyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an iso-nonyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an iso-decyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl

group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, —F, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, a cyano group, a nitro group, a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

—N(Q₃₁)(Q₃₂), —Si(Q₃₃)(Q₃₄)(Q₃₅), —B(Q₃₆)(Q₃₇), and —P(=O)(Q₃₈)(Q₃₉),

wherein Q₃₁ to Q₃₉ may be each independently selected from

—CH₃, —CD₃, —CD₂H, —CDH₂, —CH₂CH₃, —CH₂CD₃, —CH₂CD₂H, —CH₂CDH₂, —CHDC₃, —CHDCD₂H, —CHDCDH₂, —CHDCD₃, —CD₂CD₃, —CD₂CD₂H, and —CD₂CDH₂;

an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, a C₁-C₁₀ alkyl group, and a phenyl group,

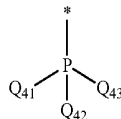
two of groups Z₁ may optionally be bound to each other to form a substituted or unsubstituted C₅-C₃₀ carbocyclic group or a substituted or unsubstituted C₂-C₃₀ heterocyclic group,

e1 may be an integer selected from 0 to 8, and

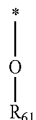
* in Formula 1 indicates a binding site to M.

In some embodiments, L₂ in Formula 1 may be selected from ligands represented by one of Formulae 13-1 to 13-49 and 14-1 to 14-28, but embodiments are not limited thereto:

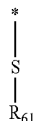
Formula 13-1



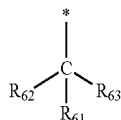
Formula 13-2



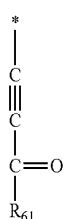
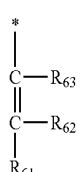
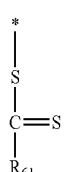
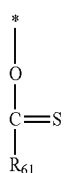
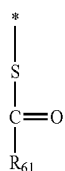
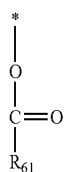
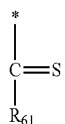
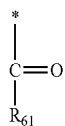
Formula 13-3



Formula 13-4



55
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56
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Formula 13-5

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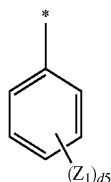


Formula 13-6

10

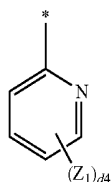
Formula 13-7

15



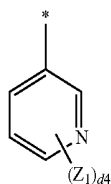
Formula 13-8

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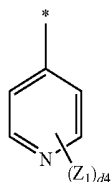
Formula 13-9

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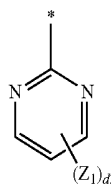
Formula 13-10

35



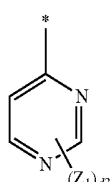
Formula 13-11

45



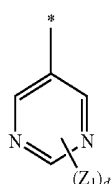
Formula 13-12

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Formula 13-13

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Formula 13-14

Formula 13-15

Formula 13-16

Formula 13-17

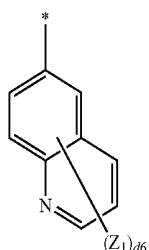
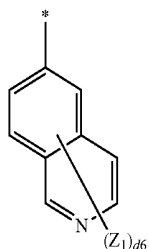
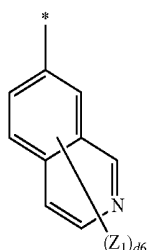
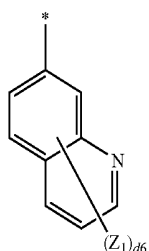
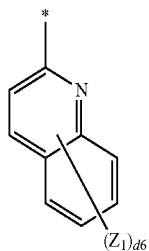
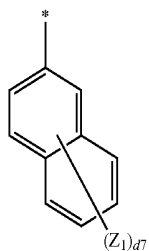
Formula 13-18

Formula 13-19

Formula 13-20

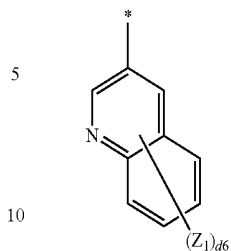
Formula 13-21

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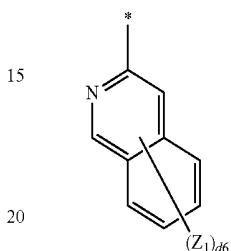


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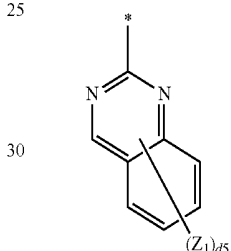
Formula 13-22



Formula 13-23

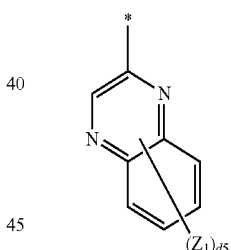


Formula 13-24

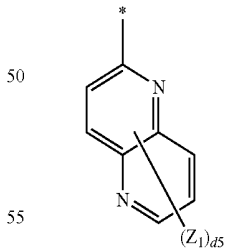


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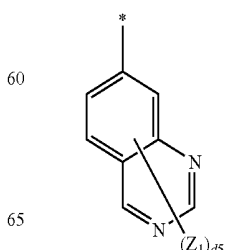
Formula 13-25



Formula 13-26



Formula 13-27



Formula 13-28

Formula 13-29

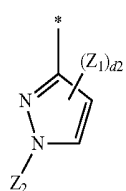
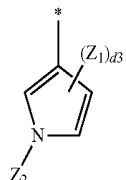
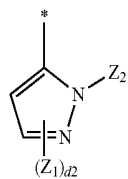
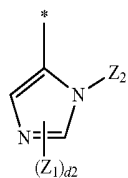
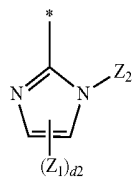
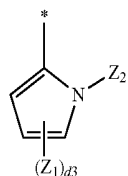
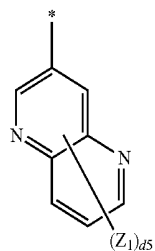
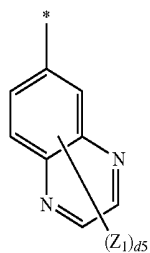
Formula 13-30

Formula 13-31

Formula 13-32

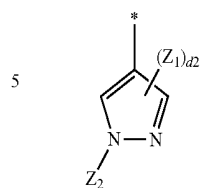
Formula 13-33

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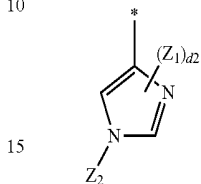


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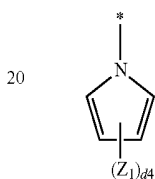
Formula 13-34



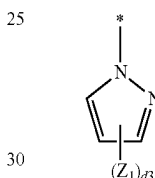
Formula 13-35



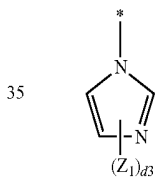
Formula 13-36



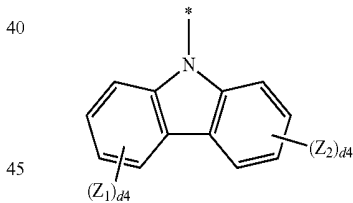
Formula 13-37



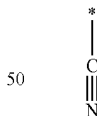
Formula 13-38



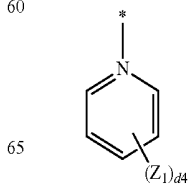
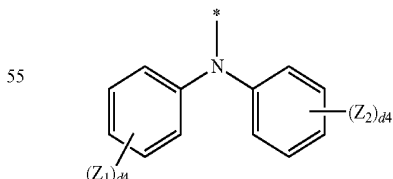
Formula 13-39



Formula 13-40



Formula 13-41



Formula 13-42

Formula 13-43

Formula 13-44

Formula 13-45

Formula 13-46

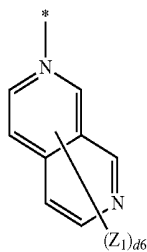
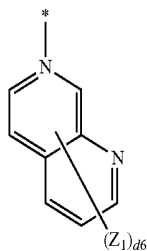
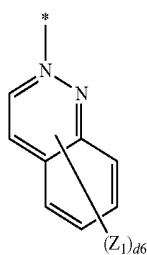
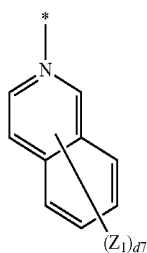
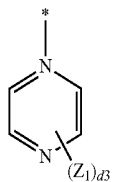
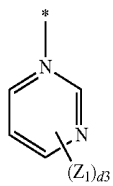
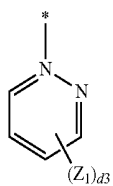
Formula 13-47

Formula 13-48

Formula 13-49

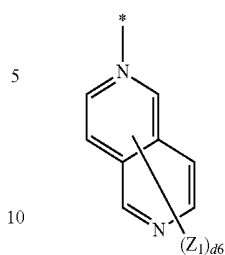
Formula 14-1

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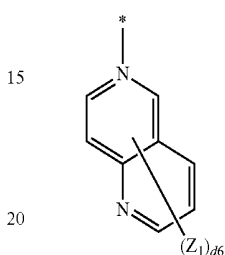


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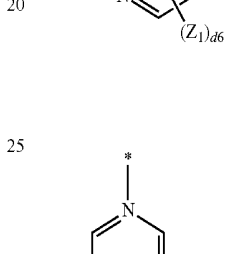
Formula 14-2



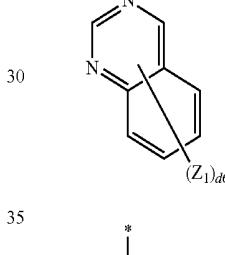
Formula 14-3



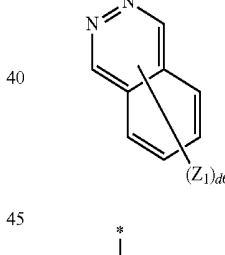
Formula 14-4



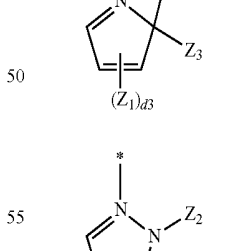
Formula 14-5



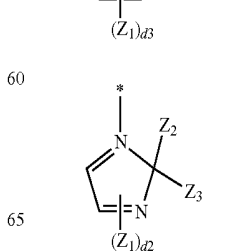
Formula 14-6



Formula 14-7



Formula 14-8



Formula 14-9

Formula 14-10

Formula 14-11

Formula 14-12

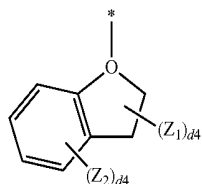
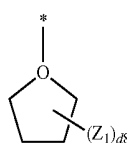
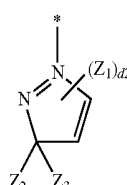
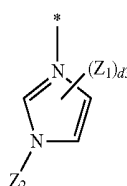
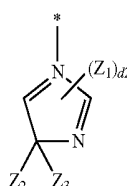
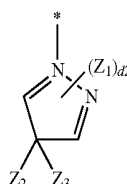
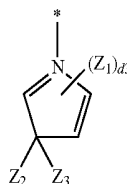
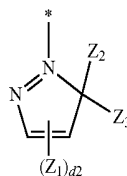
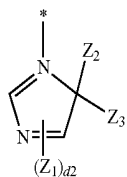
Formula 14-13

Formula 14-14

Formula 14-15

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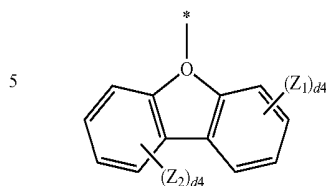
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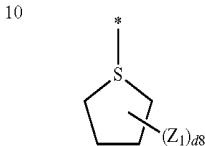
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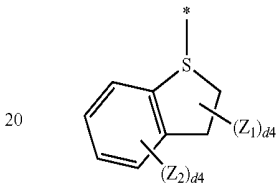
Formula 14-16



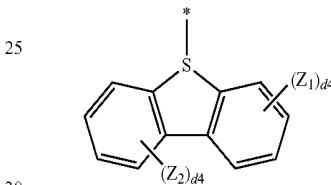
Formula 14-17



Formula 14-18



Formula 14-19



Formula 14-20

wherein, in Formulae 13-1 to 13-49 and 14-1 to 14-28,
R₆₁ may be the same as described herein,

35 Z₁ may be the same as described herein, Z₂ and Z₃ may be each independently the same as described herein in connection with Z₁,

Formula 14-21

d₂ may be an integer selected from 1 and 2,

Formula 14-22

d₃ may be an integer selected from 1 to 3,

d₄ may be an integer selected from 1 to 4,

d₅ may be an integer selected from 1 to 5,

d₆ may be an integer selected from 1 to 6,

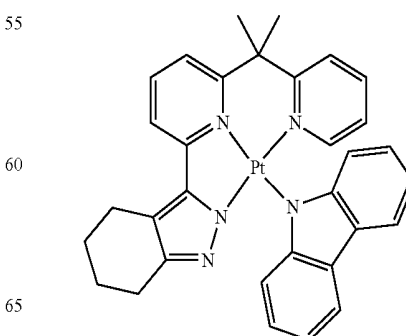
Formula 14-23

d₇ may be an integer selected from 1 to 7,

d₈ may be an integer selected from 1 to 8, and

* in Formula 1 indicates a binding site to M.

Formula 14-24



Formula 14-25

Formula 14-26

Formula 14-27

Formula 14-28

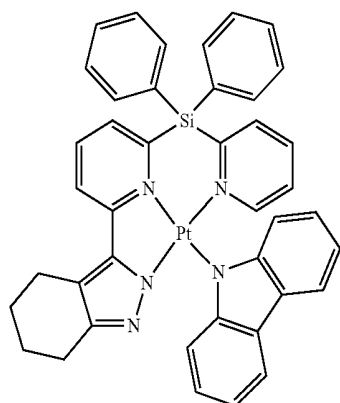
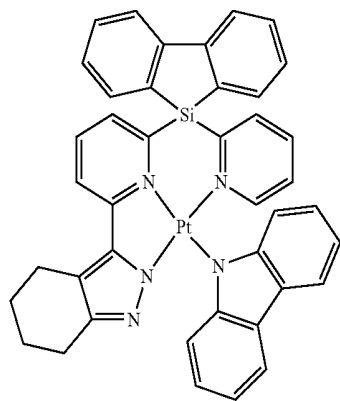
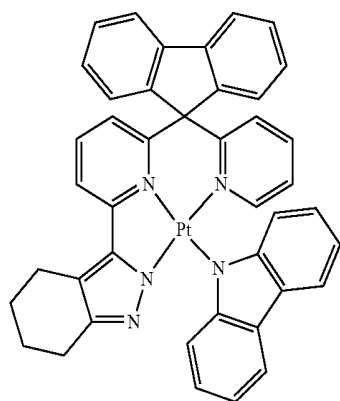
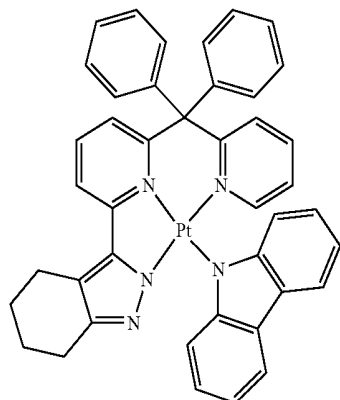
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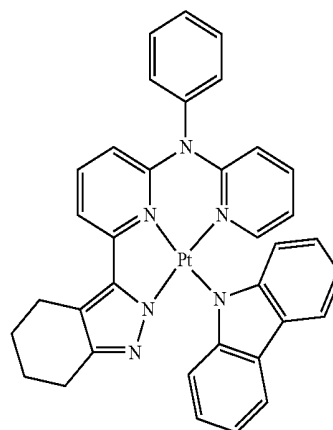


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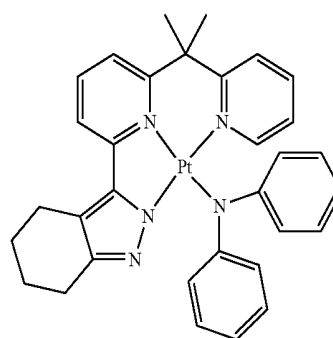
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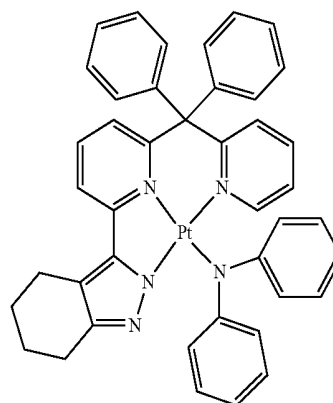


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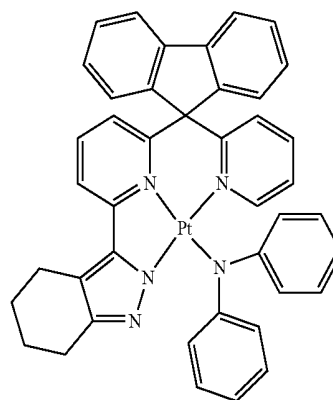
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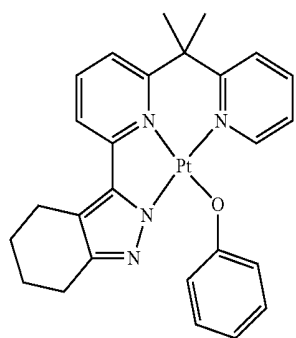
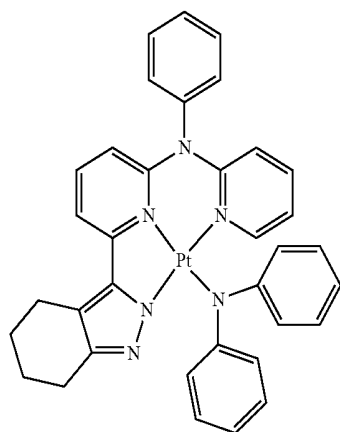
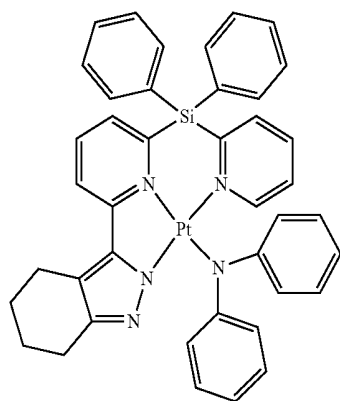
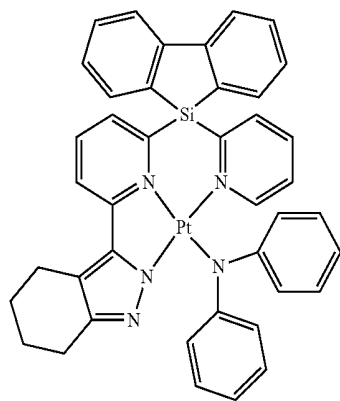
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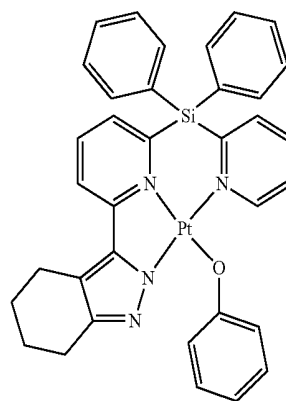
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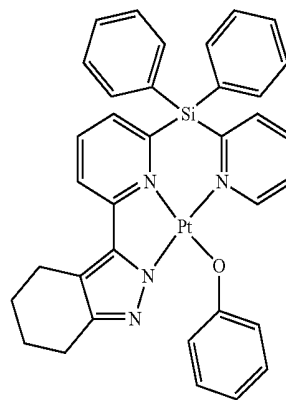
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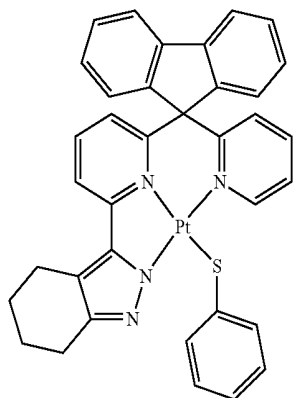
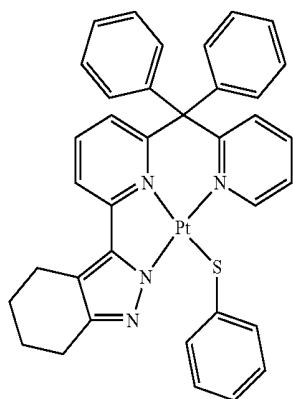
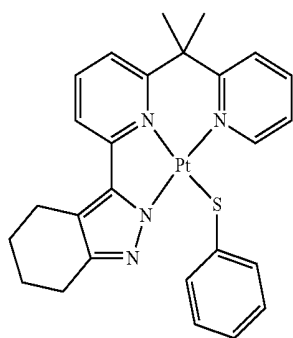
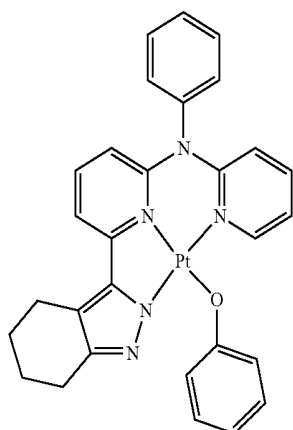
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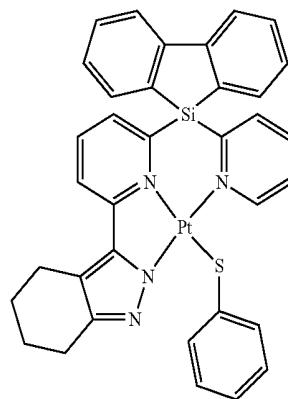
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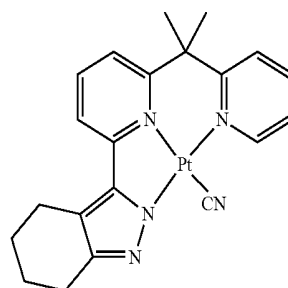
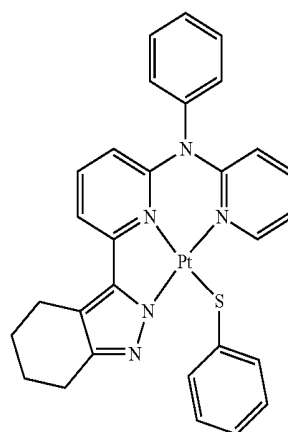
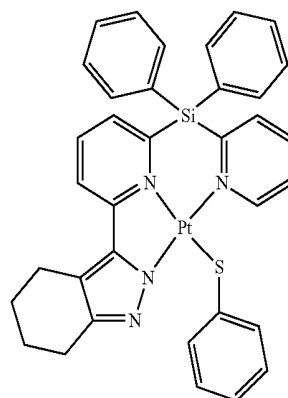
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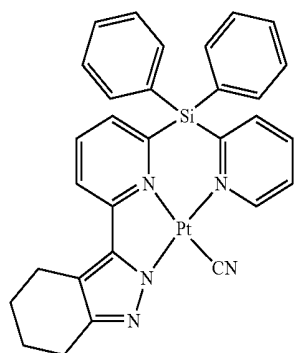
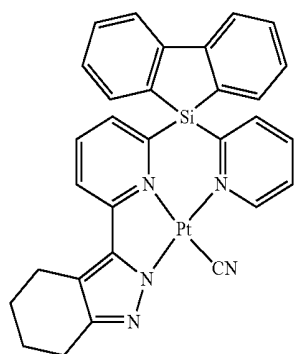
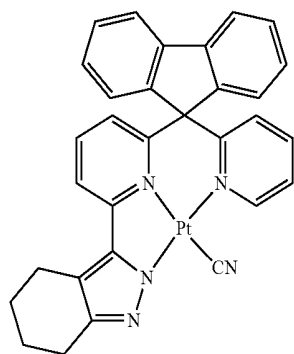
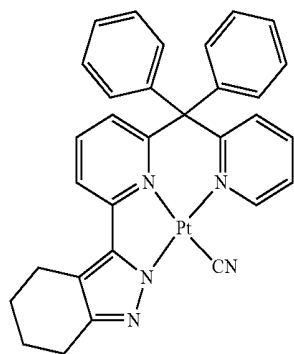
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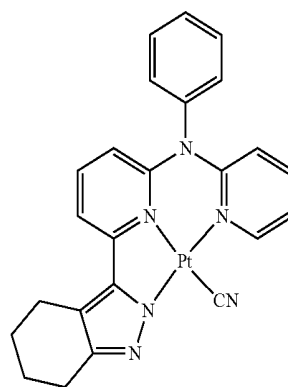
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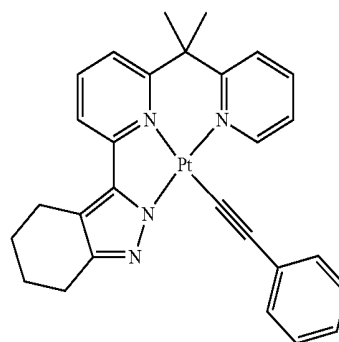
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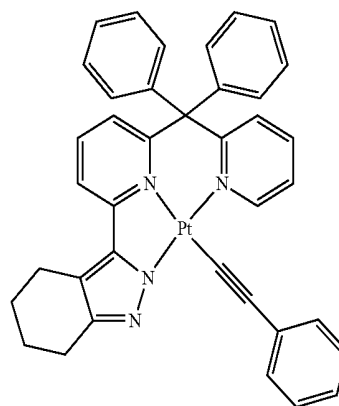
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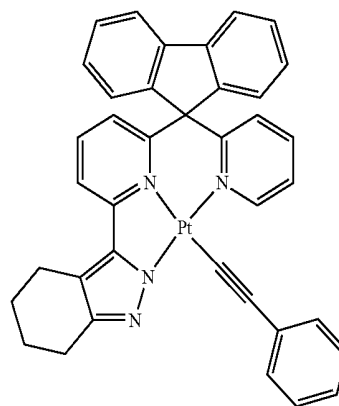
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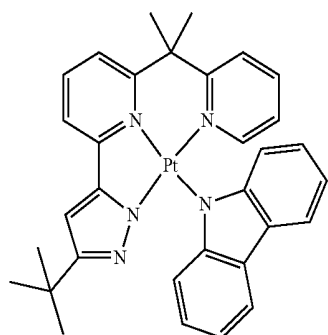
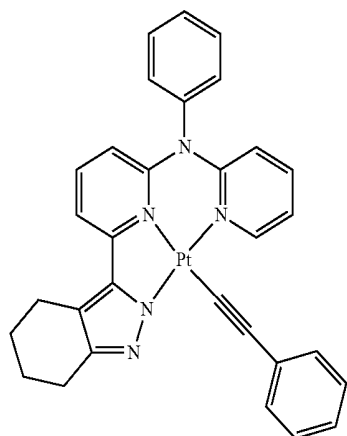
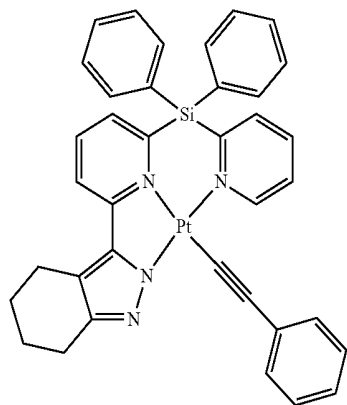
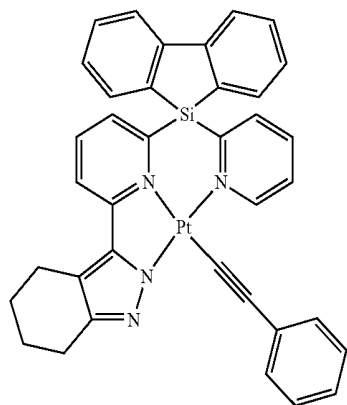
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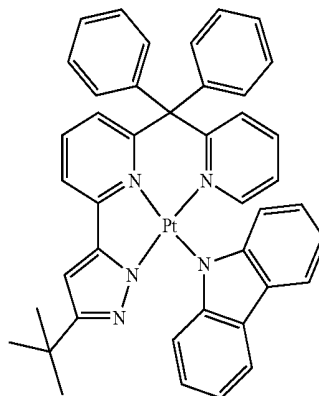
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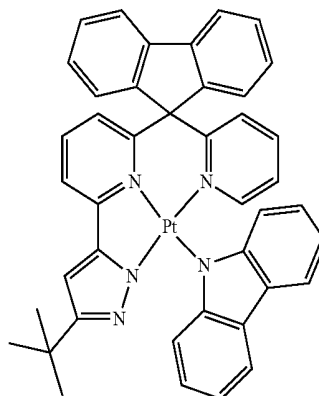


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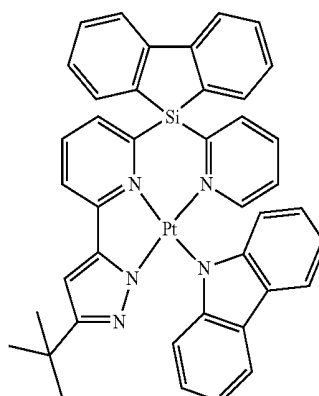


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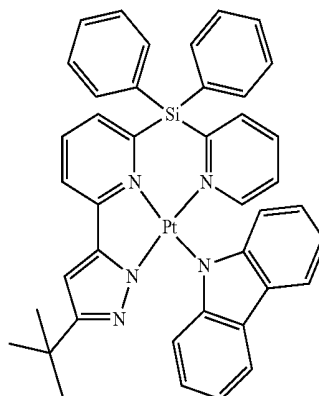
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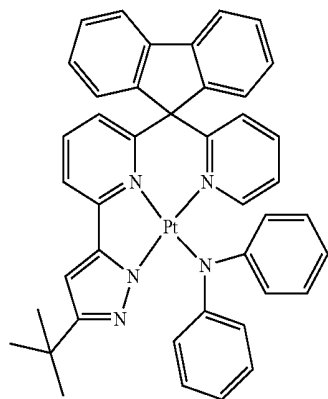
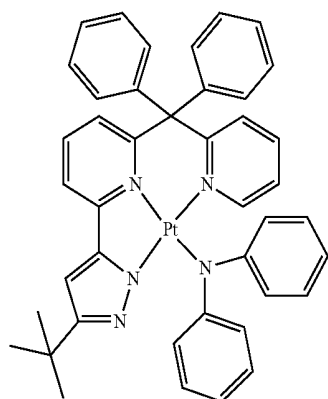
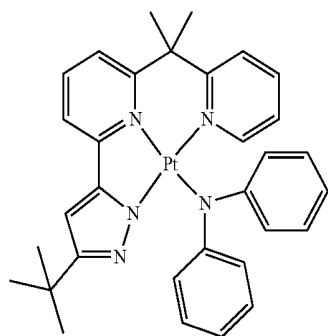
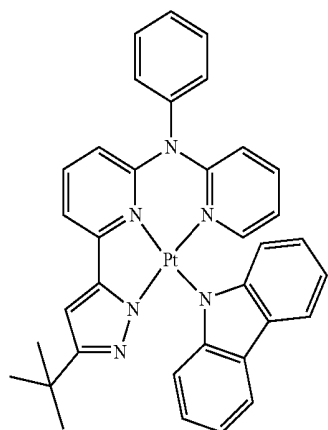
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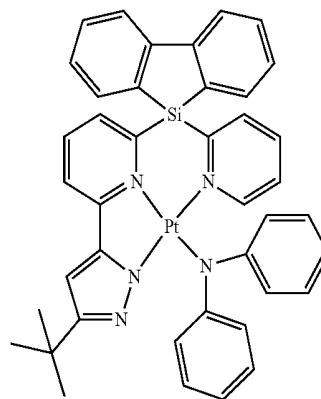
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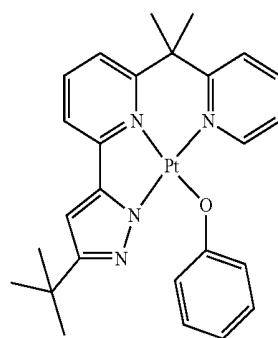
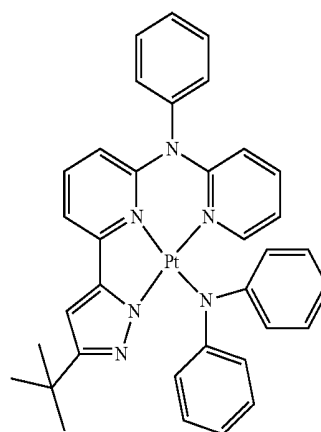
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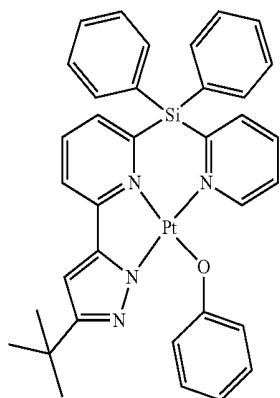
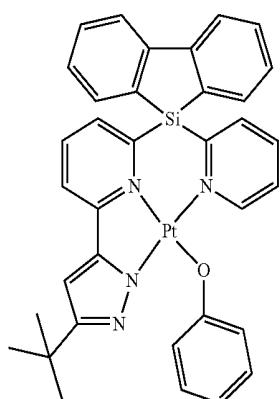
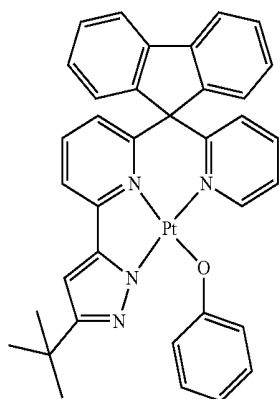
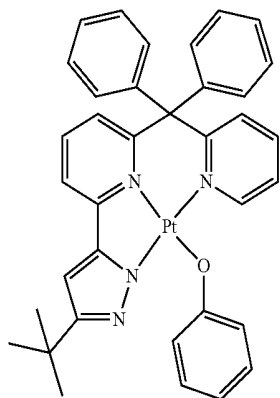
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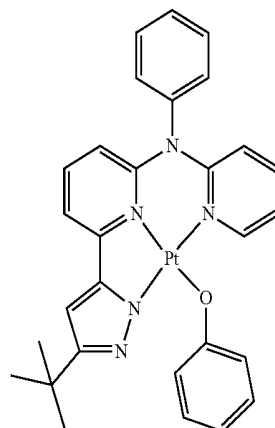
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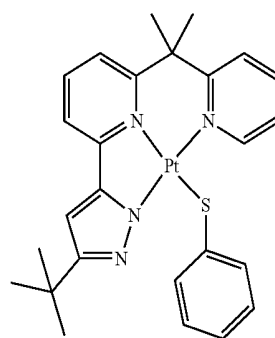
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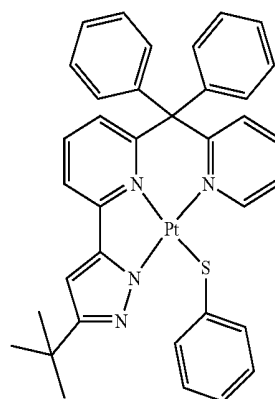
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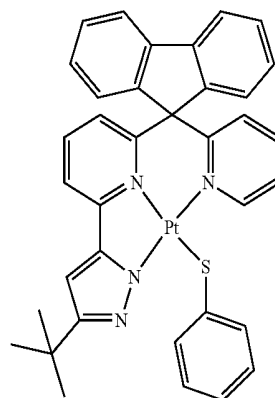
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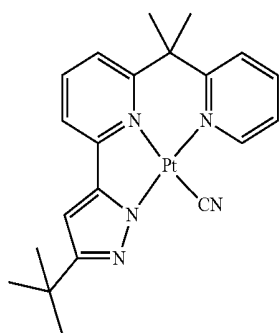
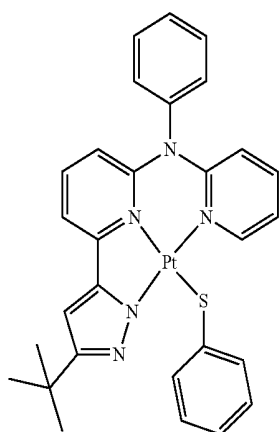
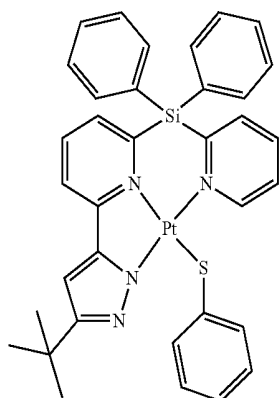
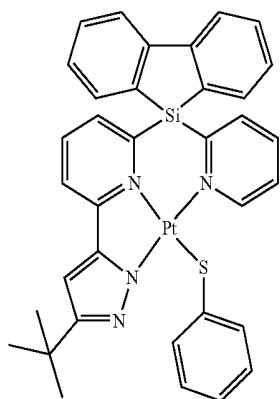
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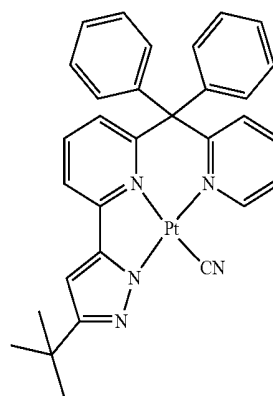
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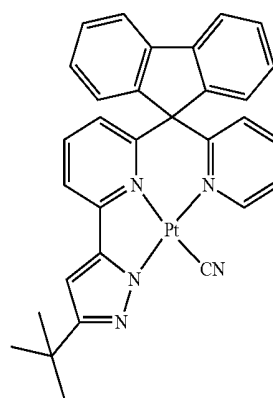
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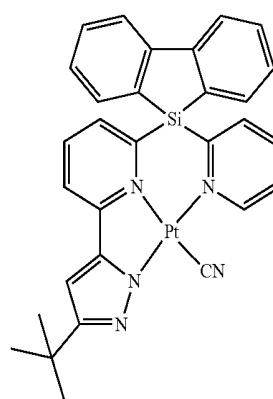
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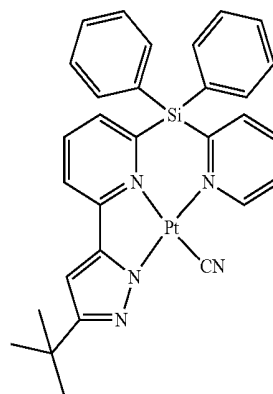
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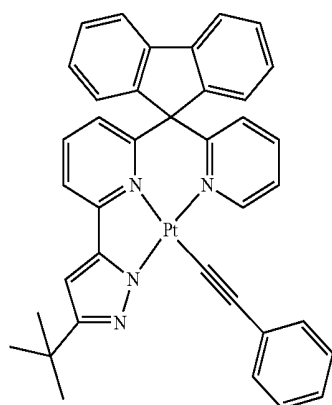
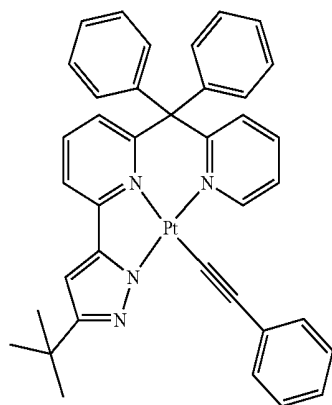
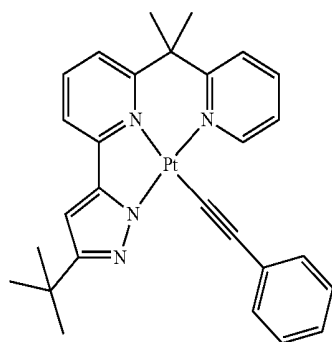
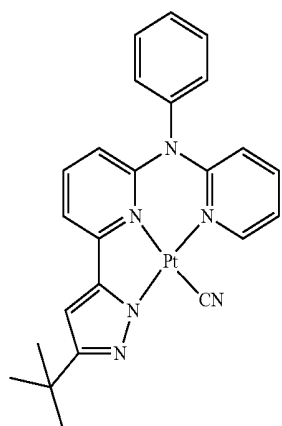
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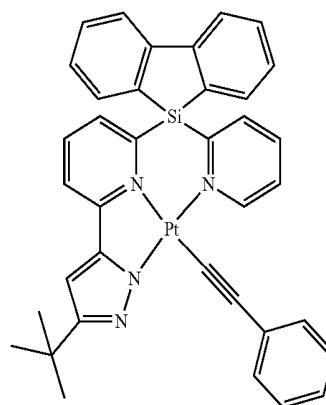
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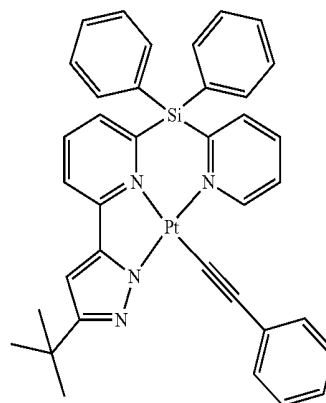
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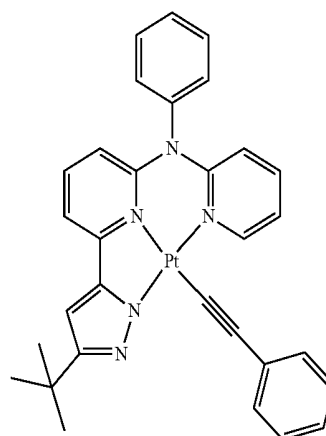


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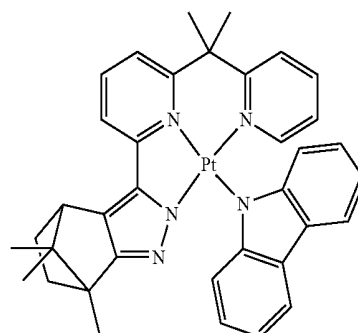
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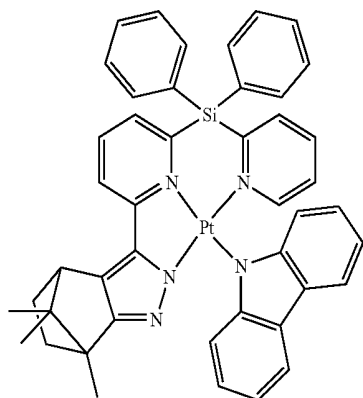
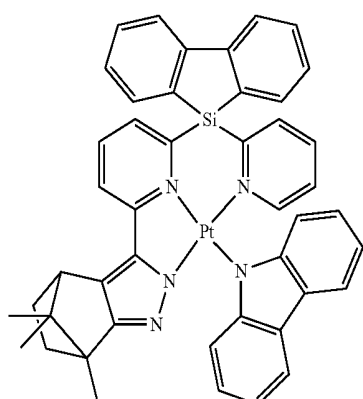
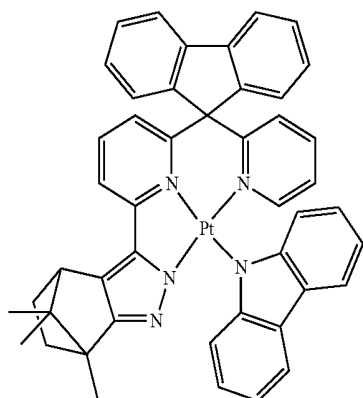
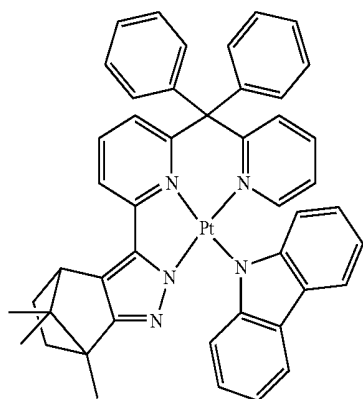
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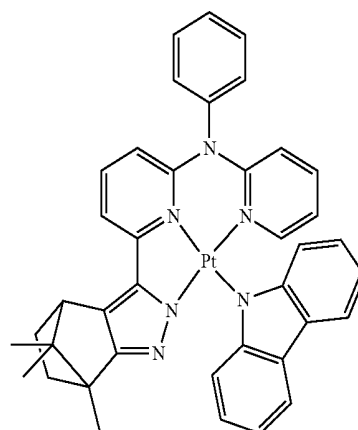
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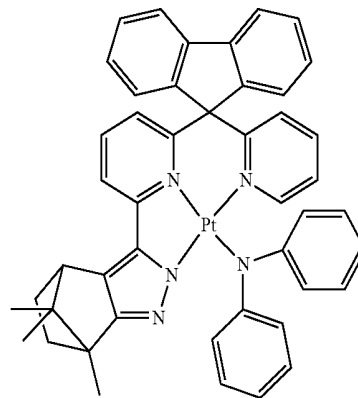
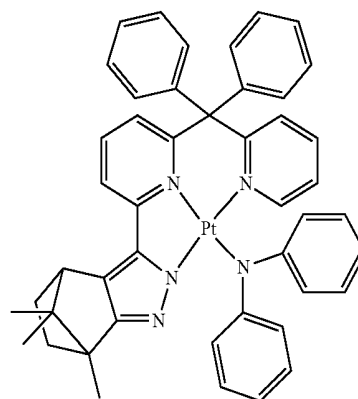
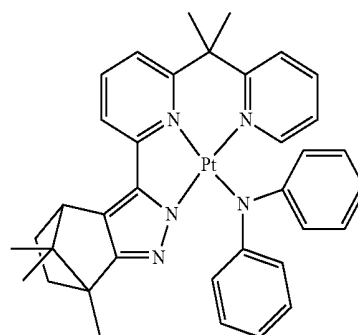
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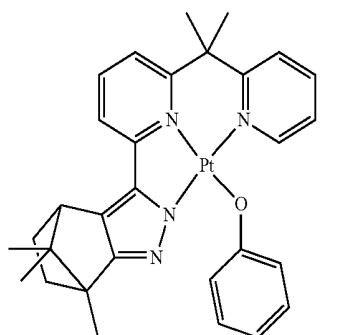
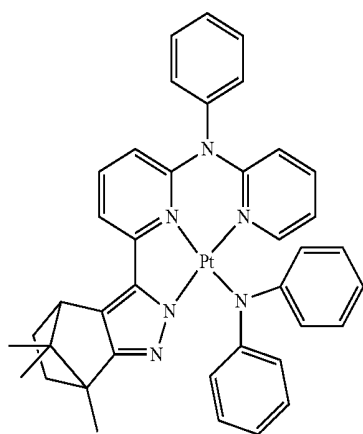
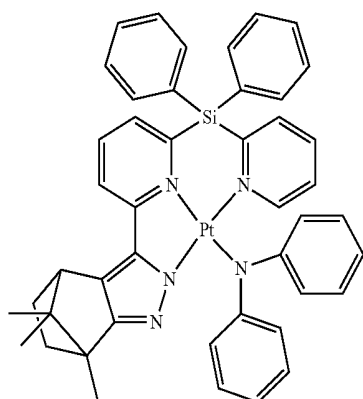
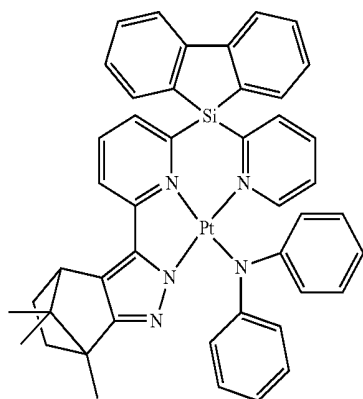
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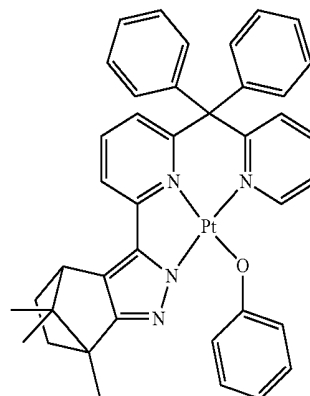
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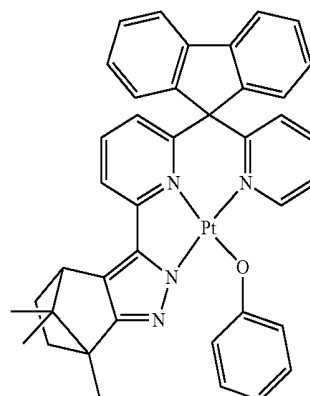
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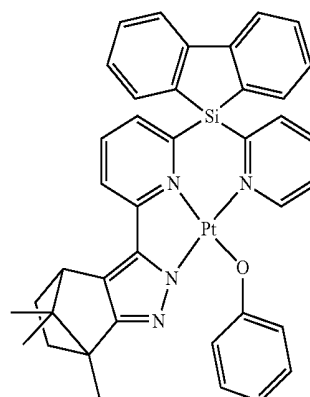


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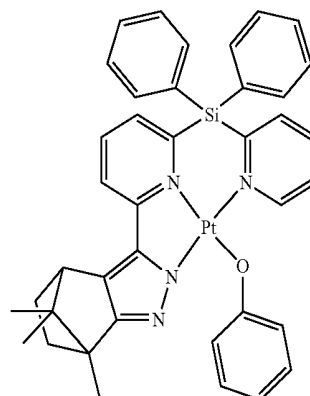


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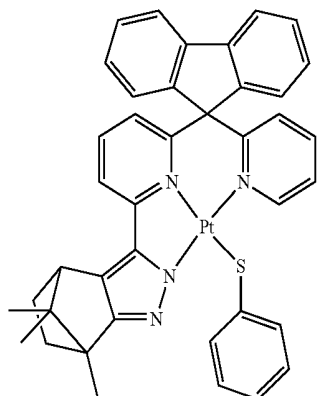
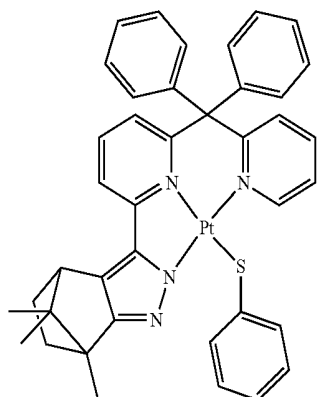
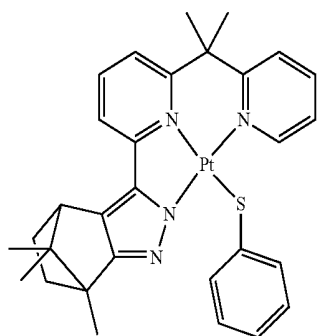
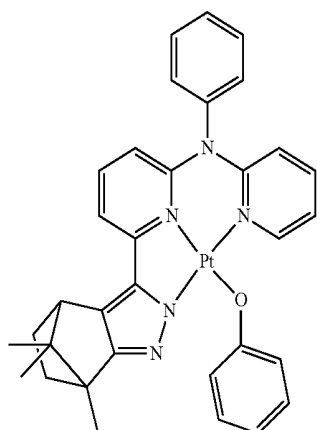
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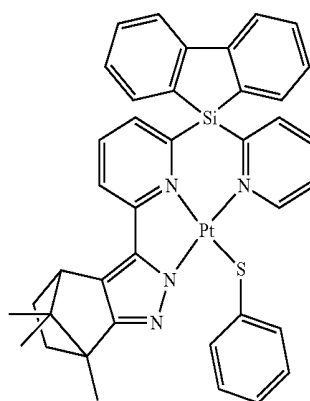
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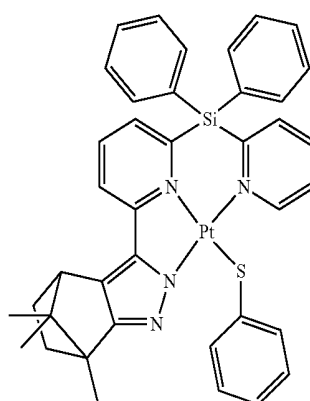
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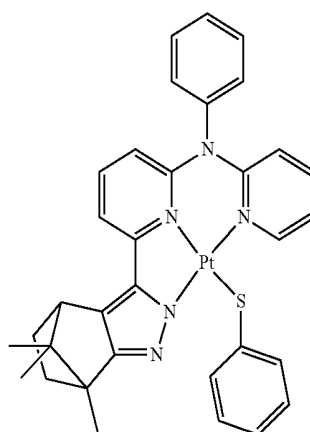
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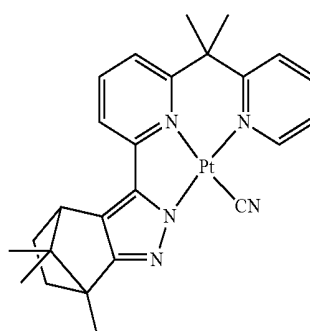


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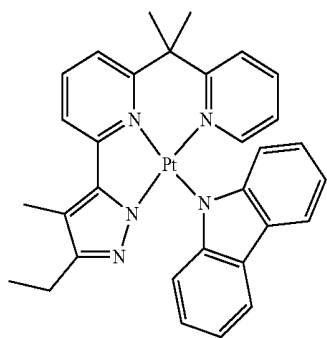
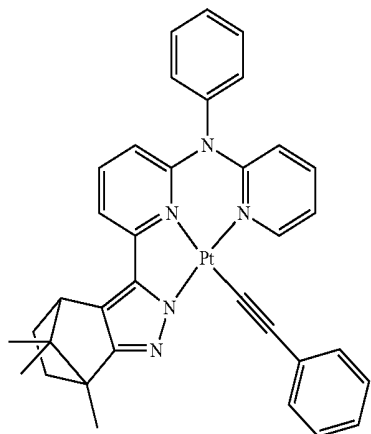
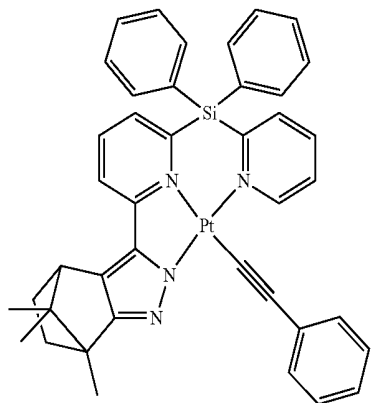
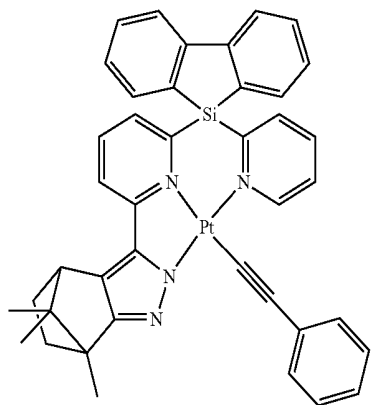
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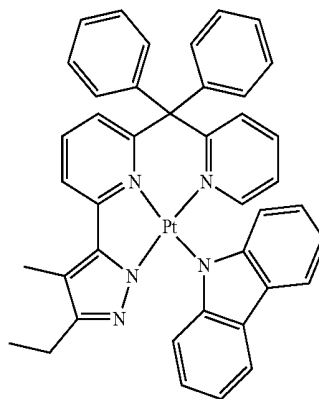
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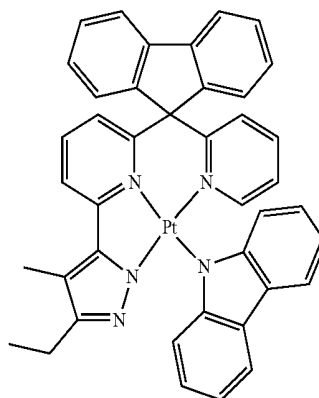
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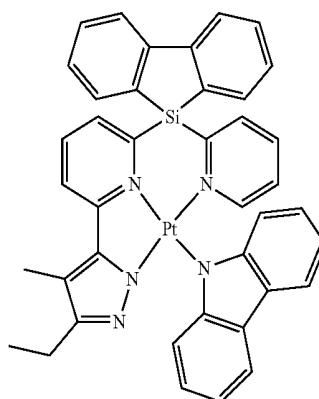
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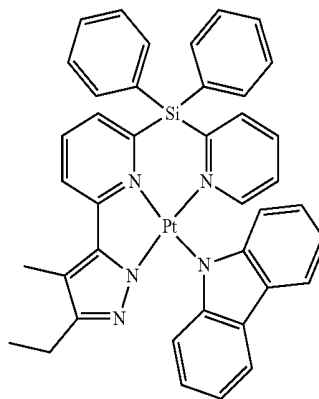
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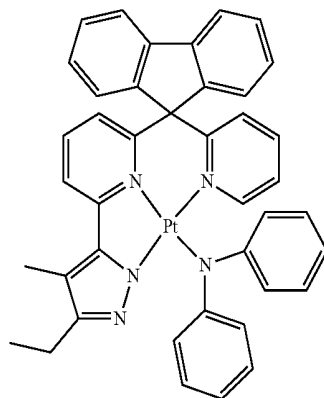
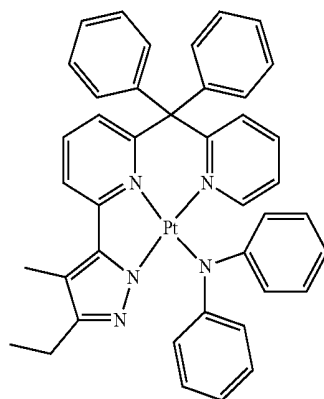
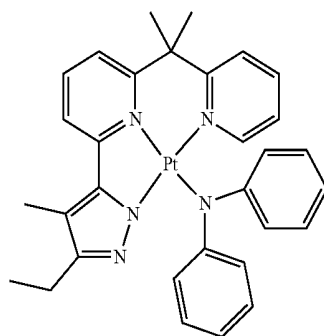
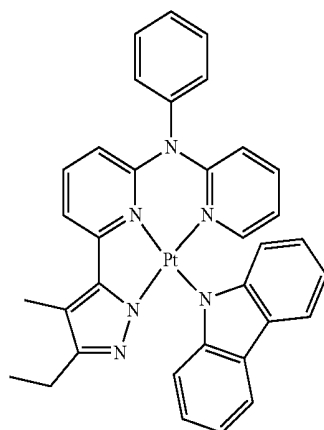
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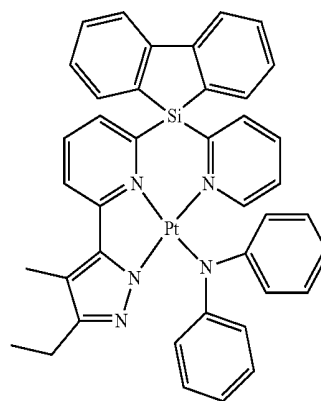
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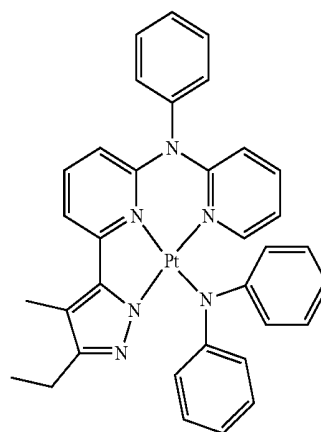
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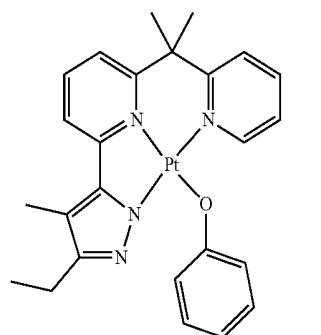


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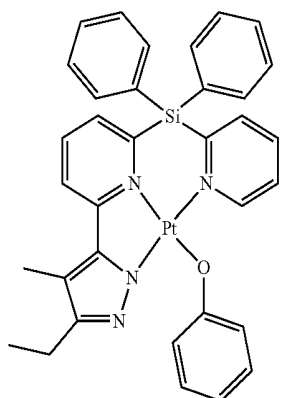
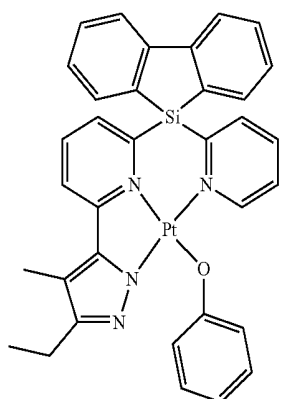
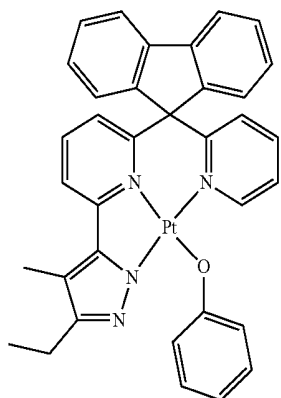
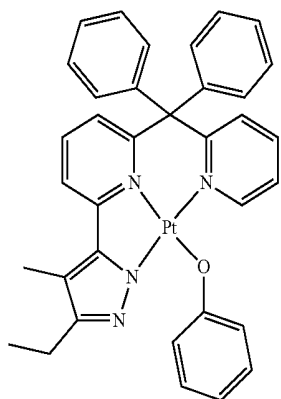
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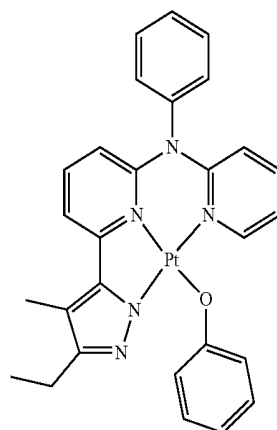
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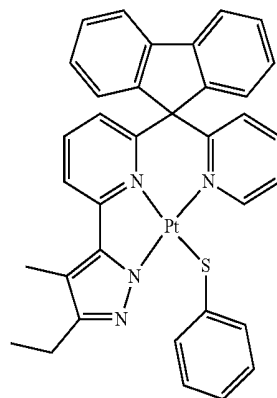
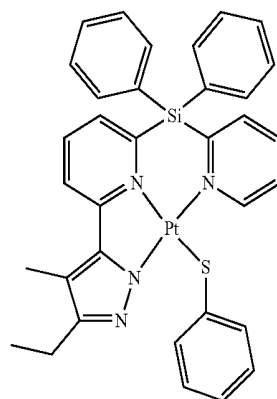
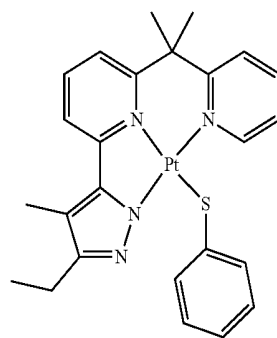
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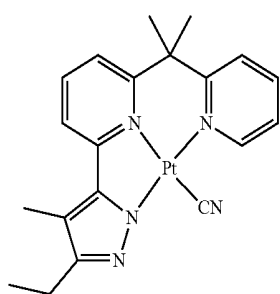
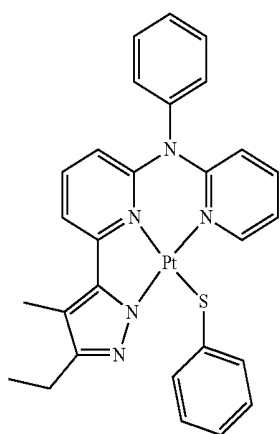
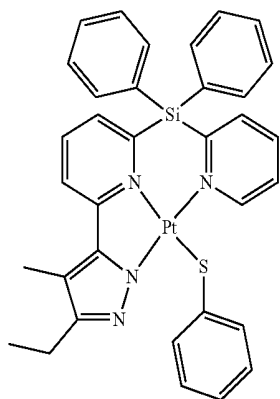
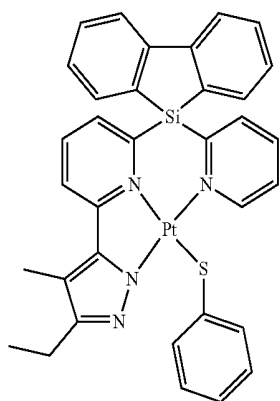
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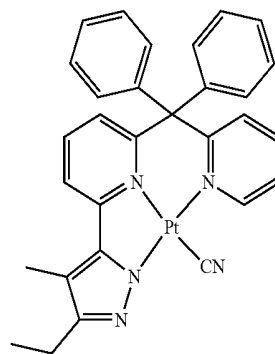
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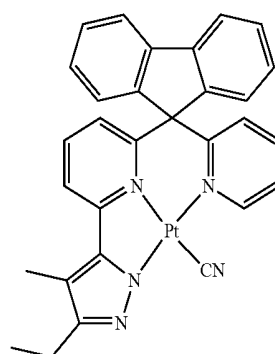
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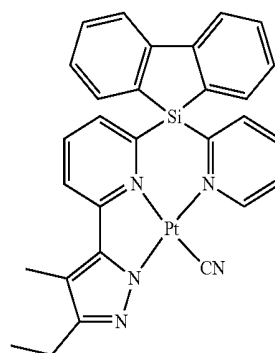
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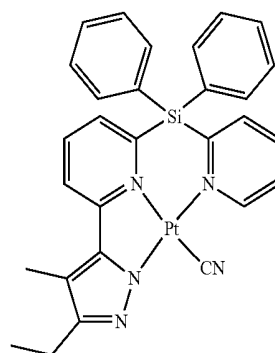
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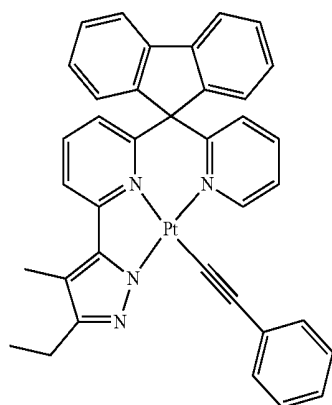
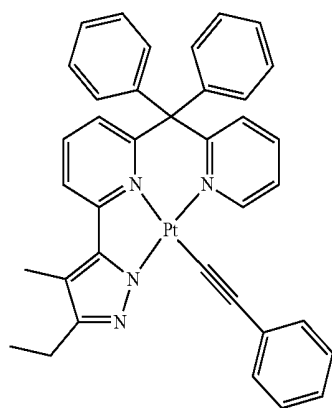
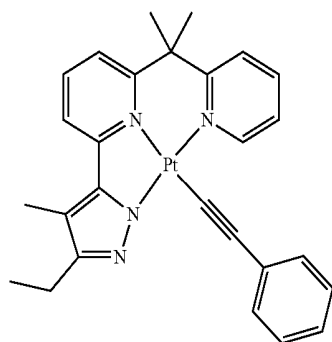
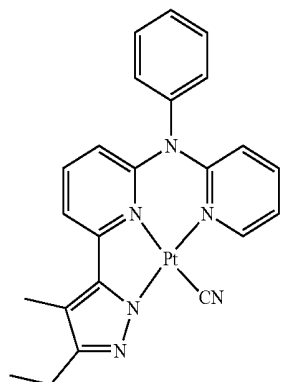
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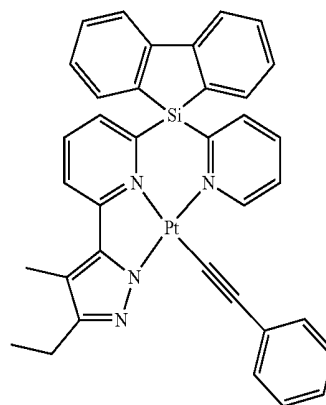
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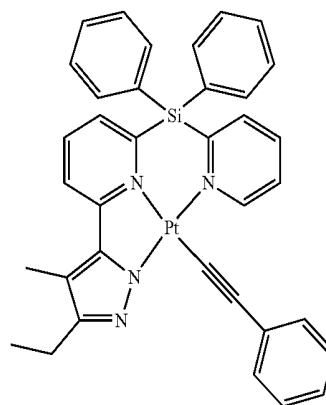
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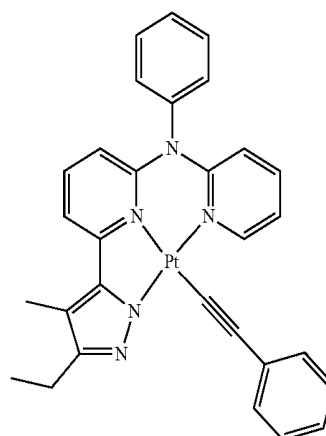
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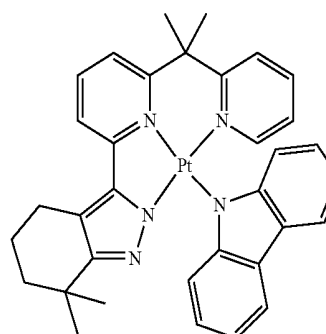


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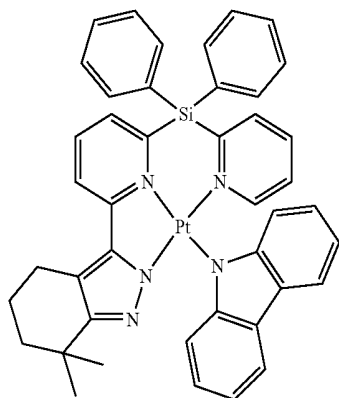
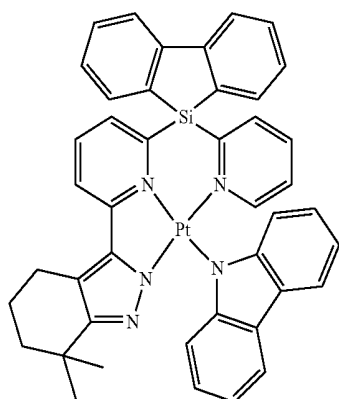
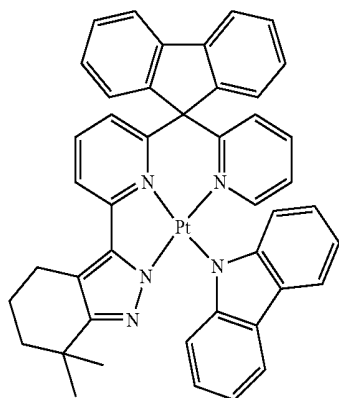
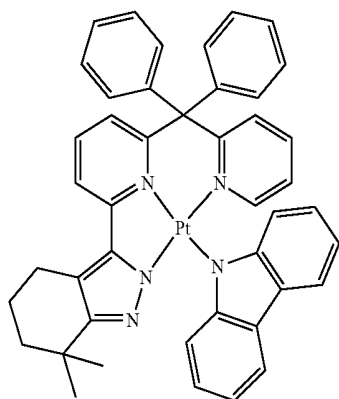
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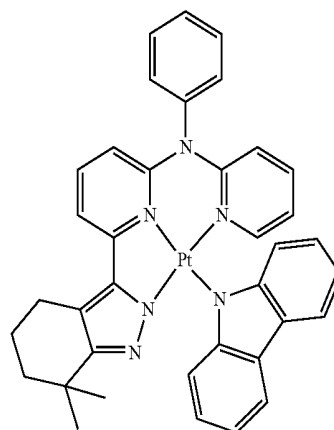
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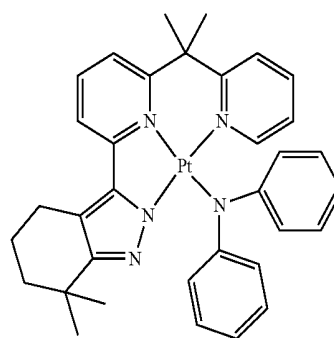
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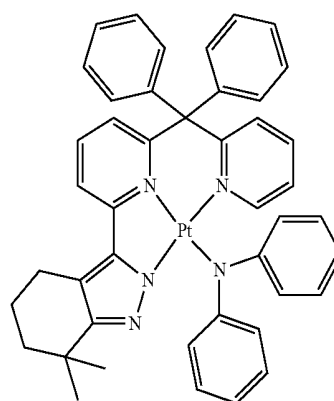
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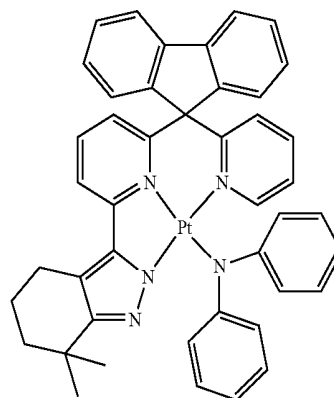
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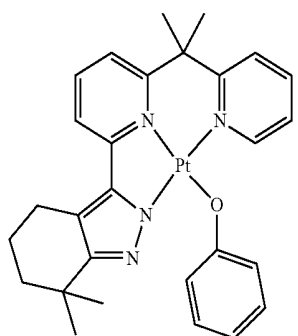
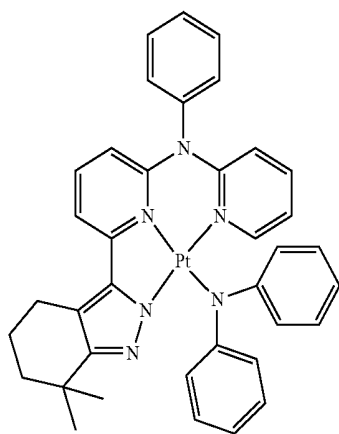
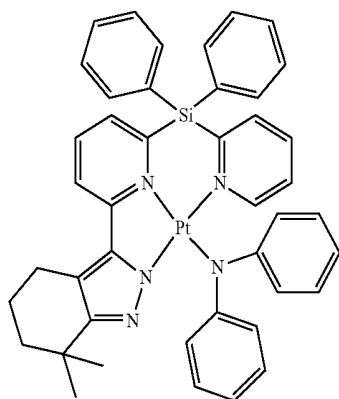
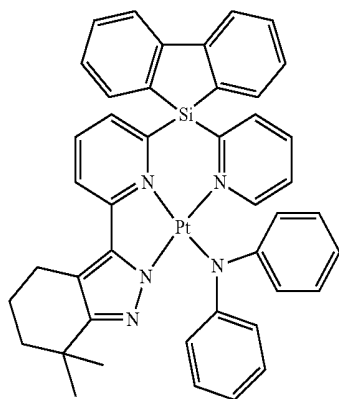
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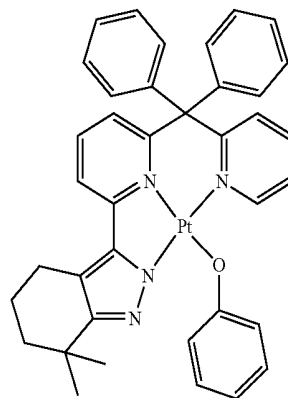
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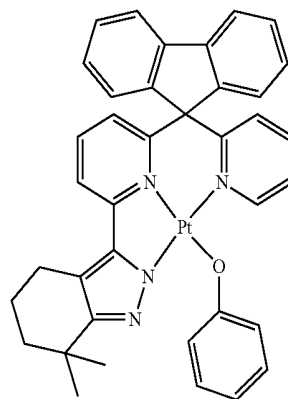


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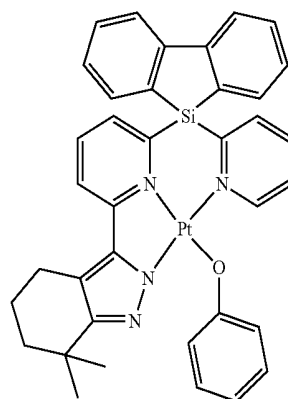


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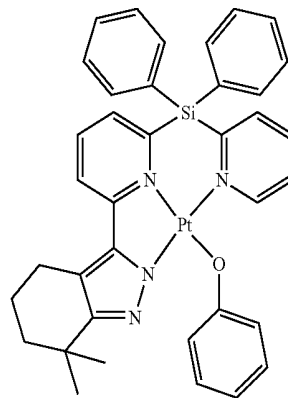


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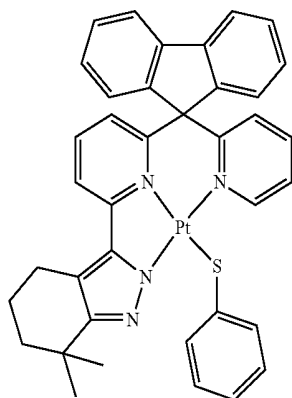
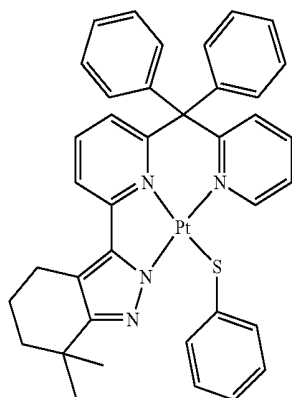
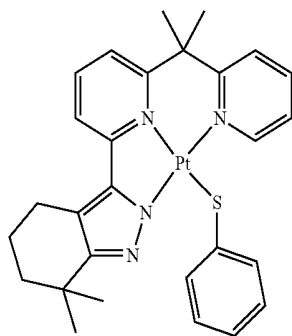
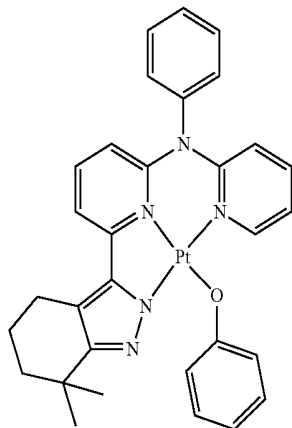
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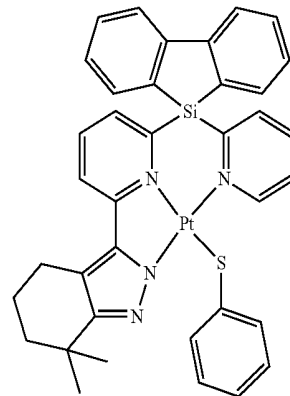
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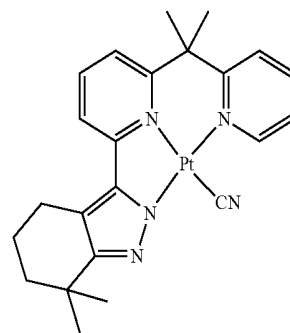
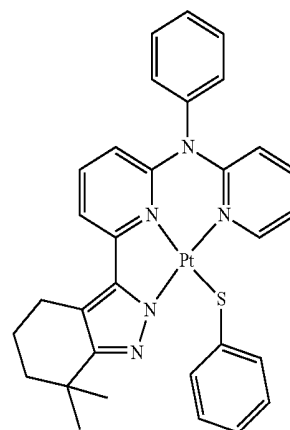
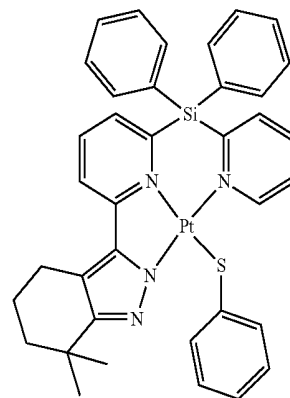
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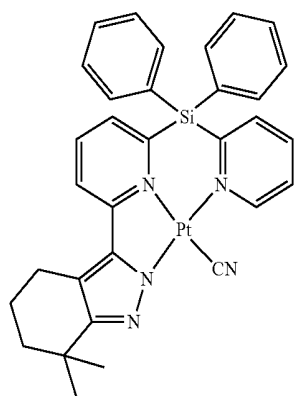
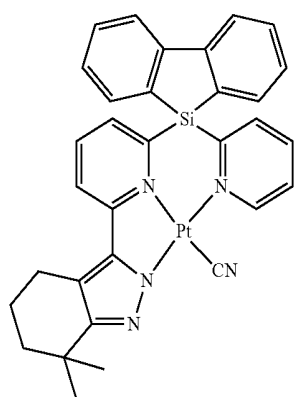
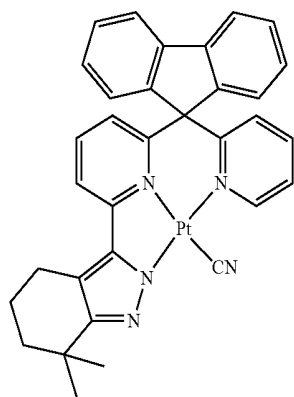
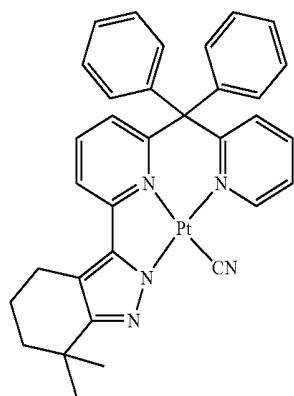
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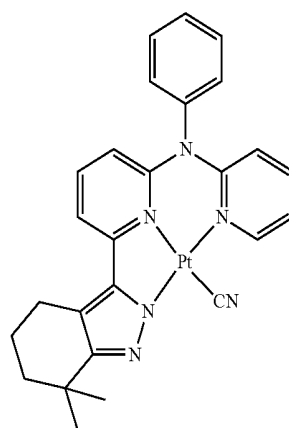
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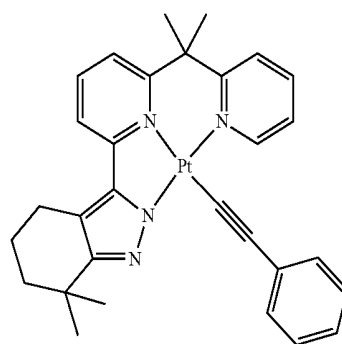
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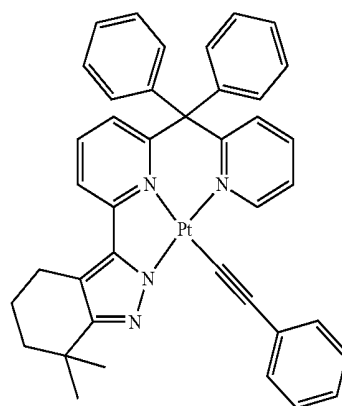


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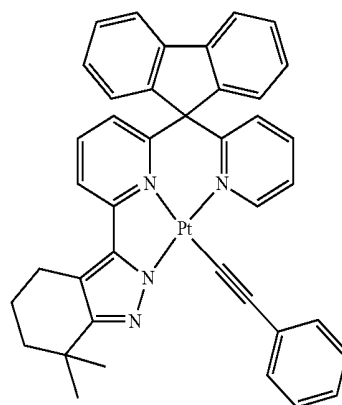


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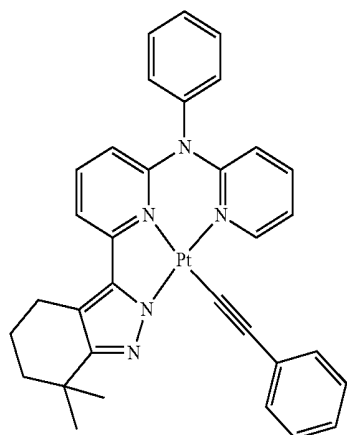
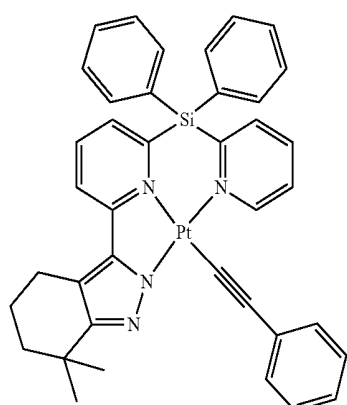
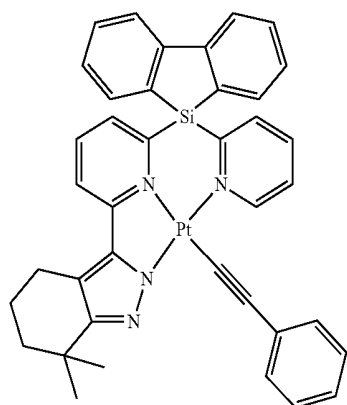
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Ligand L_1 in the organometallic compound represented by Formula 1 may be selected from ligands represented by Formula 2, provided that T_2 in Formula 2 is not a single bond. Hence, the organometallic compound represented by Formula 1 may emit light of a relatively short wavelength and have the highest occupied molecular orbital (HOMO) and the lowest unoccupied molecular orbital (LUMO) energy levels that are suitable in migration of charges. Therefore, the quality of an electron device, e.g., an organic light-emitting device that includes the organometallic compound may be excellent.

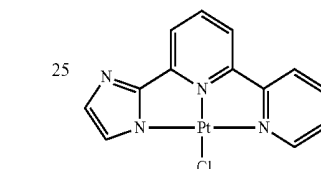
In addition, Y_1 , Y_2 , and Y_3 in Formula 2 are each nitrogen. Thus, the organometallic compound represented by Formula 1 may provide excellent emission efficiency, which lead to improved emission efficiency of an electron device, e.g., an organic light-emitting device, including the organometallic compound.

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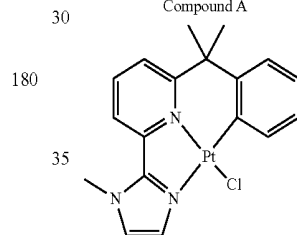
For example, the HOMO, LUMO, singlet (S_1), and triplet (T_1) energy levels of the organometallic compounds above and Compounds A and B were evaluated by using Gaussian according to a density functional theory (DFT) method (structure optimization is performed at a degree of B3LYP, and 6-31G(d,p)). The results thereof are shown in Table 1.

TABLE 1

Compound No.	HOMO (eV)	LUMO (eV)	S_1 energy level (eV)	T_1 energy level (eV)
33	-4.864	-1.722	2.557	2.445
34	-4.902	-1.913	2.423	2.32
69	-4.920	-1.766	2.568	2.454
70	-4.960	-1.954	2.438	2.337
105	-4.850	-1.712	2.554	2.450
106	-4.876	-1.904	2.406	2.314
108	-4.772	-1.688	3.084	2.518
141	-4.872	-1.728	2.559	2.443
142	-4.906	-1.922	2.419	2.317
177	-4.897	-1.731	2.581	2.456
178	-4.922	-1.924	2.431	2.330
A	-5.488	-2.800	2.103	1.809
B	-5.094	-2.236	2.166	2.035



Compound A



Compound B

Referring to the results of Table 1, the organometallic compound of Formula 1 was found to have suitable electric characteristics as a dopant for use in an electron device, e.g., an organic light-emitting device.

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

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 that is 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.

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 power, high quantum efficiency, long lifespan, and excellent color coordination.

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 represented by Formula 1 may be included in the emission layer. In this regard, the organometallic compound may act as a dopant, and the emission layer may further include a host (that is, an amount of the organometallic compound represented by Formula 1 may be less than an amount of the host).

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

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

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

For example, in the organic light-emitting device, the first electrode may be an anode, the second electrode may be a cathode, and the organic layer may further include a hole transport region disposed between the first electrode and the emission layer and an electron transport region disposed between the emission layer and the second electrode, wherein the hole transport region may include a hole injection layer, a hole transport layer, an electron blocking layer, or any combinations thereof, and the electron transport region may include a hole blocking layer, an electron transport layer, an electron injection layer, or any combinations thereof.

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

The FIGURE 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 the FIGURE. The organic light-emitting device 10 includes a first electrode 11, an organic layer 15, and a second electrode 19, which are sequentially stacked in this stated order.

A substrate 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 a transparent plastic substrate, each having excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and water-resistance.

The first electrode 11 may be formed by vacuum depositing or sputtering a material for forming the first electrode 11 on the substrate. The first electrode 11 may be an anode. The material for forming the first electrode 11 may be

selected from materials with a high work function to facilitate hole injection. The first electrode 11 may be a reflective electrode, a semi-transmissive electrode, or a transmissive electrode. The material for forming the first electrode 11 may be an indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO₂), or zinc oxide (ZnO). In various embodiments, the material for forming 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).

The first electrode 11 may have a single-layered structure or a multi-layered 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.

The organic layer 15 is disposed on the first electrode 11.

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

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

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

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

When the hole transport region includes a hole injection layer, the hole injection layer may be formed on the first electrode 11 by using one or more suitable methods, for example, vacuum deposition, spin coating, casting, and/or Langmuir-Blodgett (LB) deposition.

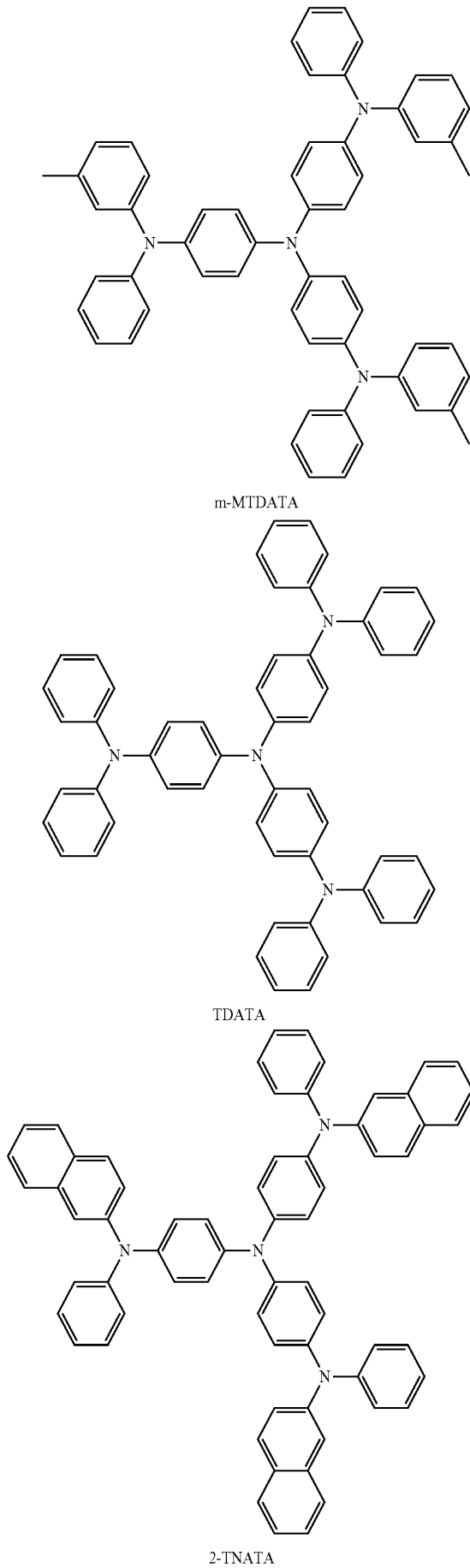
When a hole injection layer is formed by vacuum deposition, the deposition conditions may vary according to a material that is used to form the hole injection layer, and the structure and thermal characteristics of the hole injection layer. For example, the deposition conditions may include a deposition 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.

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

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

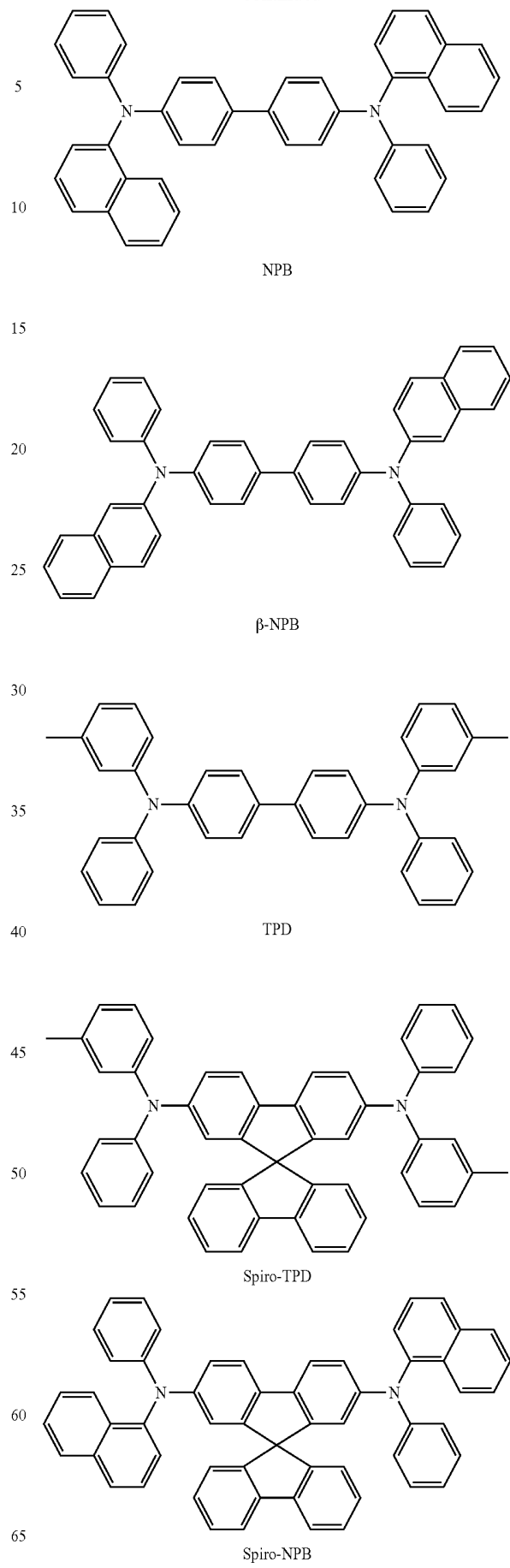
The hole transport region may include at least one selected from m-MTDATA, TDATA, 2-TNATA, NPB, β-NPB, TPD, Spiro-TPD, Spiro-NPB, methylated-NPB, TAPC, HMTPD, 4,4',4"-tris(N-carbazolyl)triphenylamine (TCTA), polyaniline/dodecylbenzene sulfonic acid (Pani/DBSA), poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate) (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:

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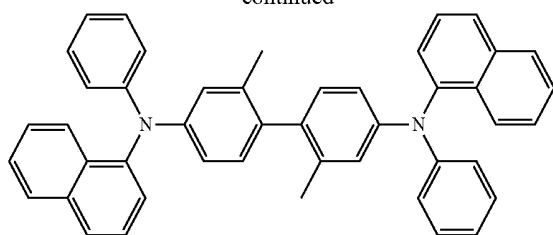
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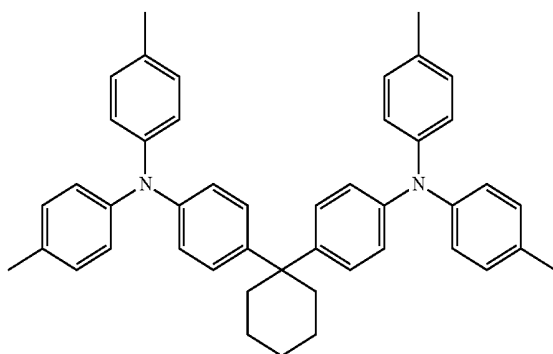


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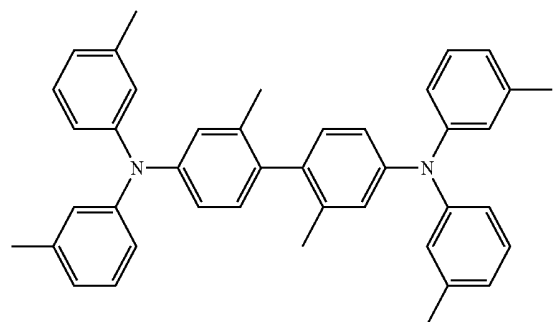
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methylated NPB

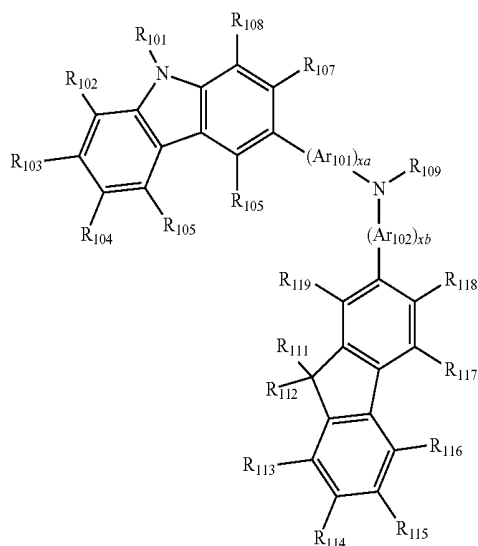


TAPC



HMTPD

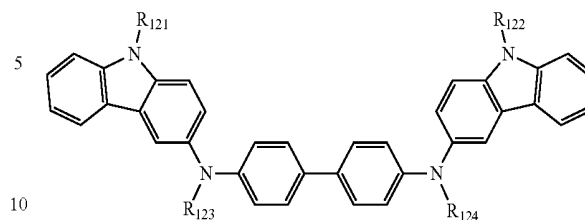
Formula 201



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Formula 202



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

15 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 phenalenylenylene group, a phenanthrenylene group, an anthracenylenylene group, a fluoranthenylenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylenylene group, a naphthacenylenylene group, a picenylene group, a perylenylene group, and a pentacenylene group; and

25 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 phenalenylenylene group, a phenanthrenylene group, an anthracenylenylene group, a fluoranthenylenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylenylene group, a naphthacenylenylene group, a picenylene group, a perylenylene group, and a pentacenylene group, each substituted with at least one selected from a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro 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.

In Formula 201, xa and xb may be each independently an integer selected from 0 to 5. Alternatively, xa and xb may be each independently an integer selected from 0, 1, and 2. In some embodiments, xa may be 1 and xb may be 0, but

50 embodiments are not limited thereto.

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

hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid 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 (e.g., a methyl group, an ethyl group, a propyl group, a butyl group, pentyl group, or a hexyl group), and a C₁-C₁₀ alkoxy group (e.g., a methoxy group, an ethoxy group, a propoxy group, a butoxy group, or a pentoxy group);

60 a C₁-C₁₀ alkyl group and a C₁-C₁₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt

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thereof, a sulfonic acid group or a salt thereof, and a phosphoric acid group or a salt thereof;

a phenyl group, a naphthyl group, an anthracenyl group, a fluorenyl group, and a pyrenyl group; and

a phenyl group, a naphthyl group, an anthracenyl group, a fluorenyl group, and a pyrenyl 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-C₁₀ alkyl group, and a C₁-C₁₀ alkoxy group, but embodiments are not limited thereto.

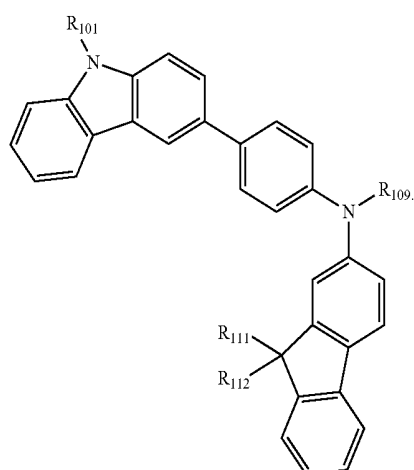
R₁₀₉ in Formula 201 may be selected from

a phenyl group, a naphthyl group, an anthracenyl group, and a pyridinyl group; and

a phenyl group, a naphthyl group, an anthracenyl group and a pyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid 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.

In some embodiments, the compound represented by Formula 201 may be represented by Formula 201A, but embodiments are not limited thereto:

Formula 201A

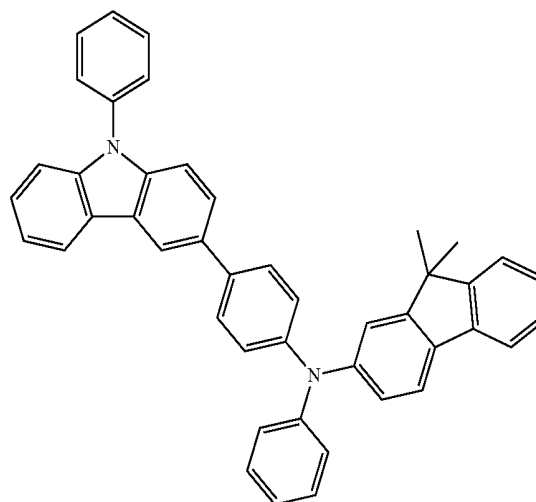


R₁₀₁, R₁₁₁, R₁₁₂, and R₁₀₉ in Formula 201A may be the same as those described herein.

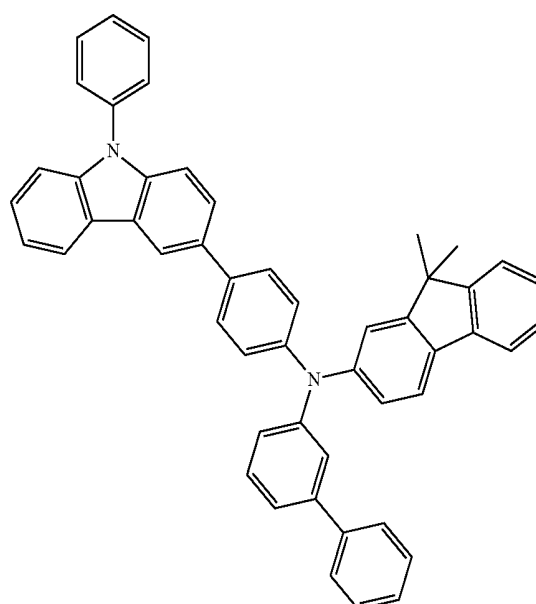
For example, the compound represented by Formula 201 and the compound represented by Formula 202 may include Compounds HT1 to HT20, but embodiments are not limited thereto:

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HT1

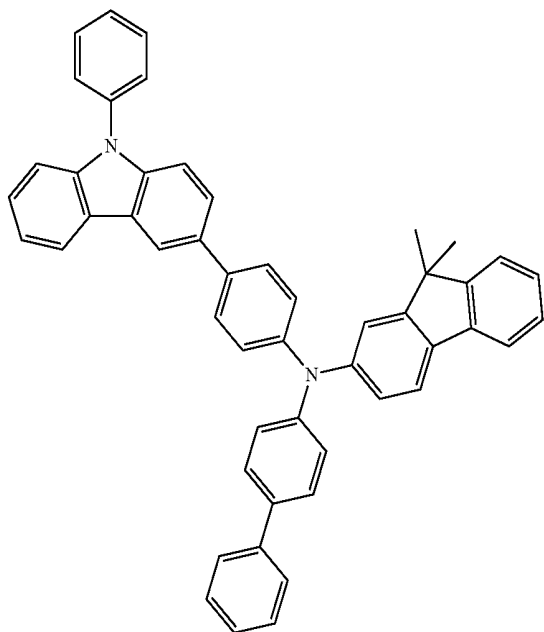


HT2



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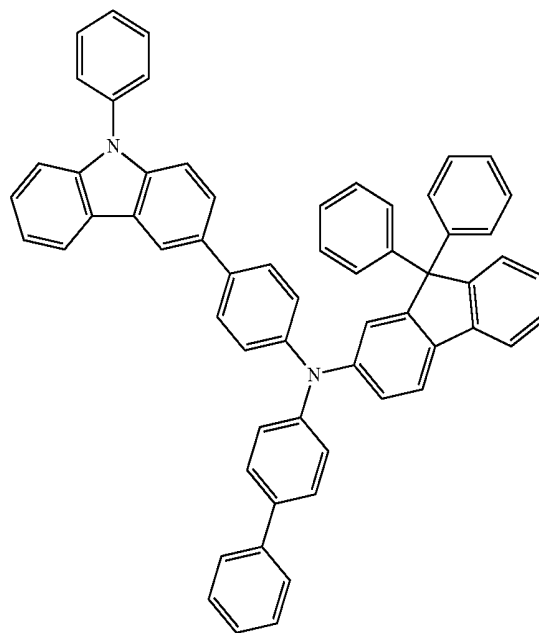
HT3



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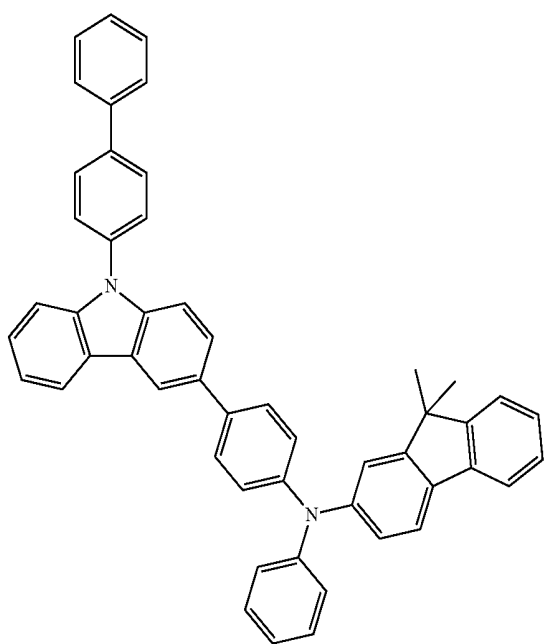
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HT5



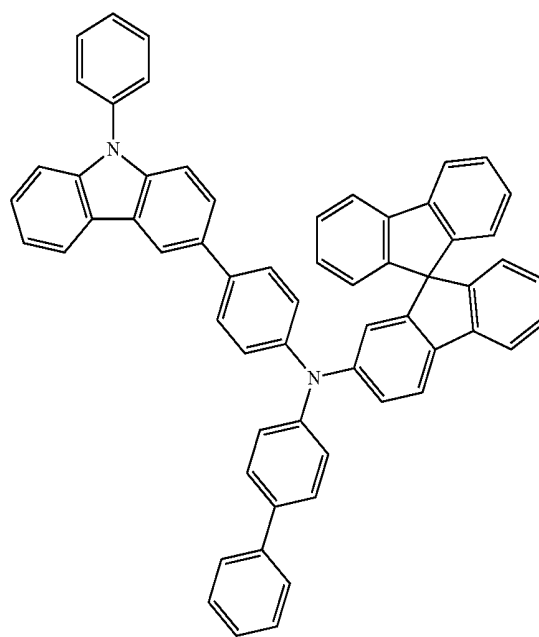
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HT4



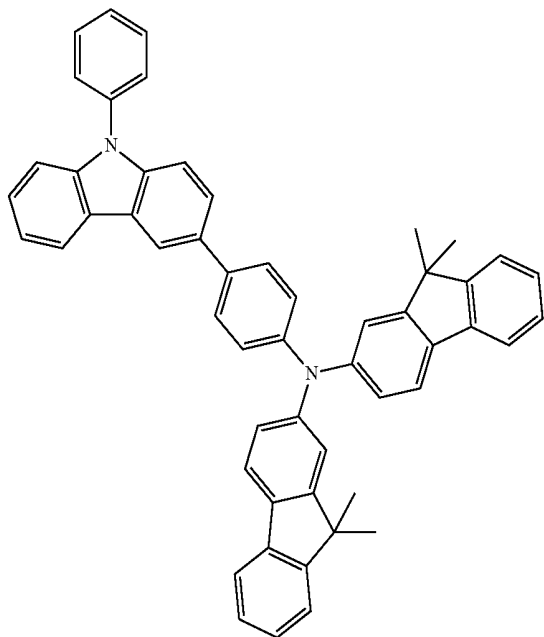
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HT6



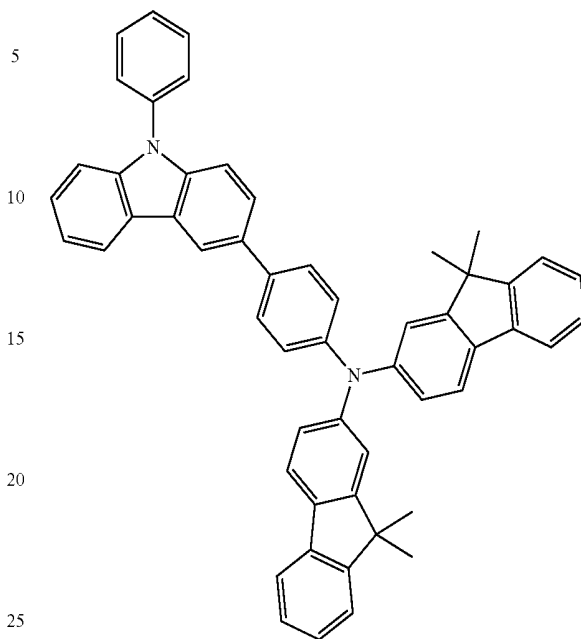
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HT7



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HT9



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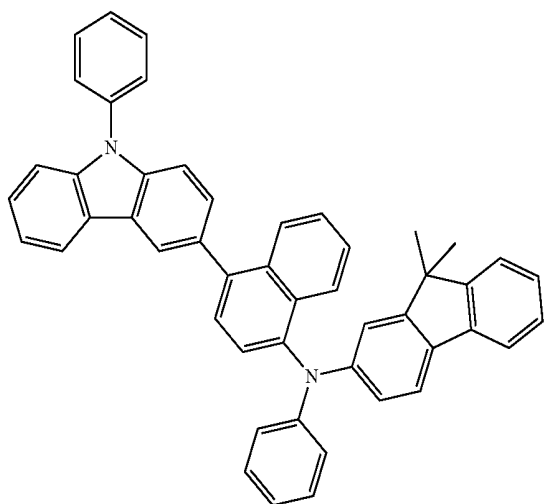
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HT10

HT8



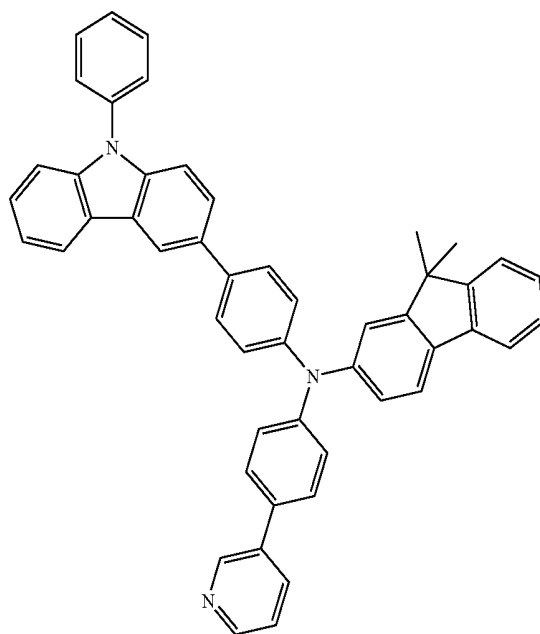
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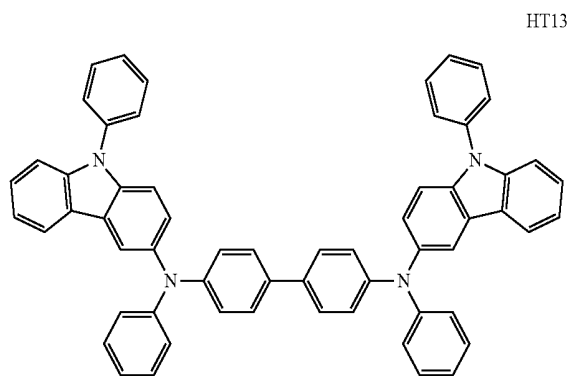
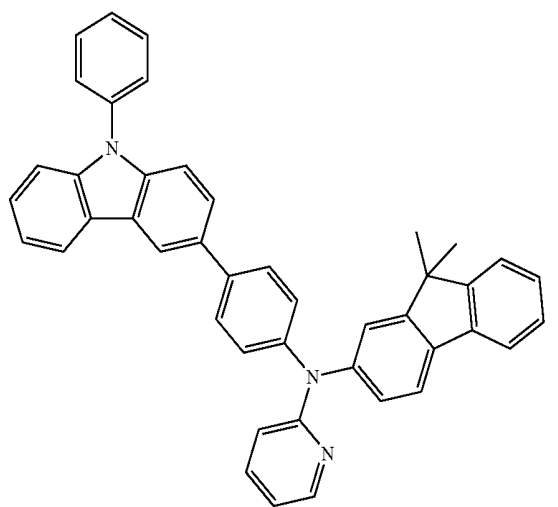
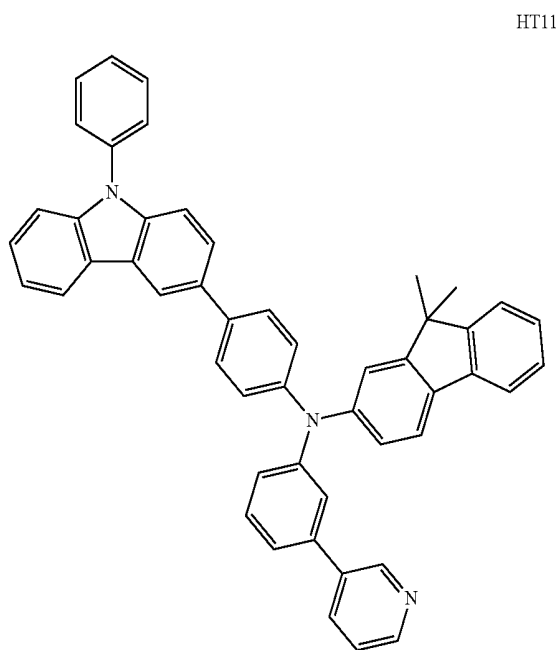
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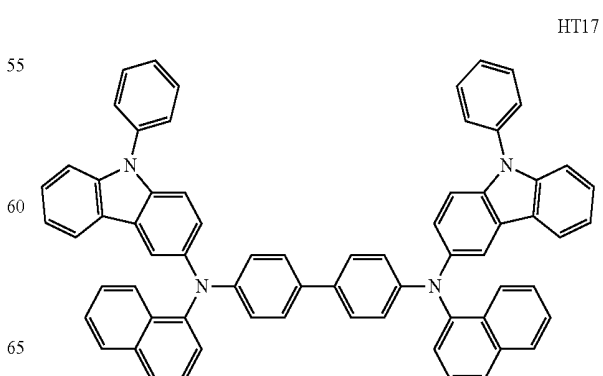
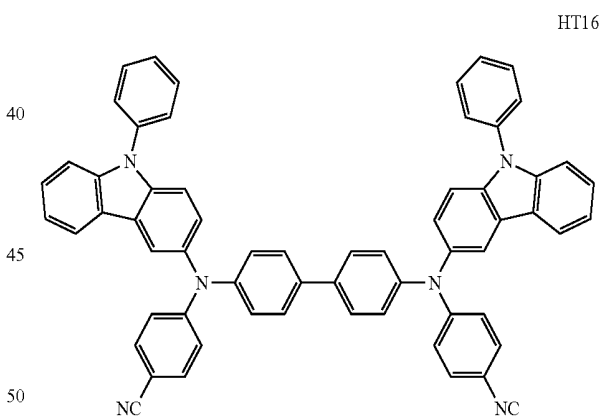
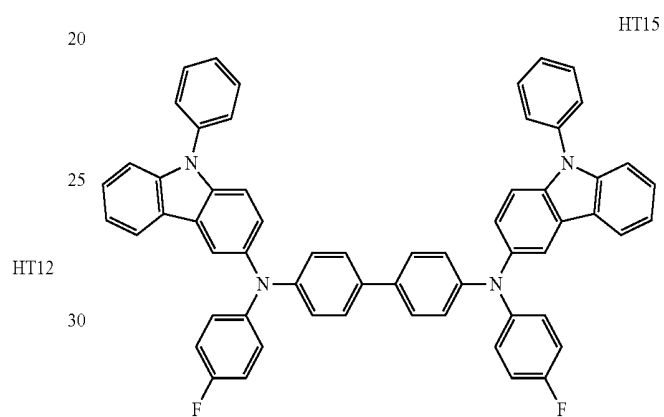
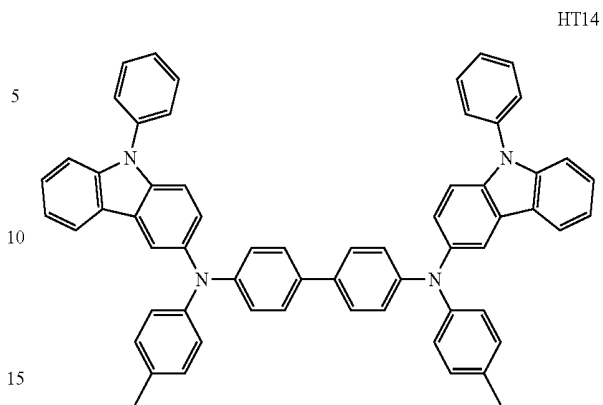
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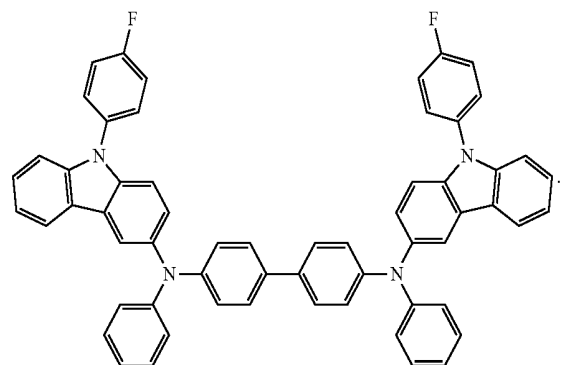
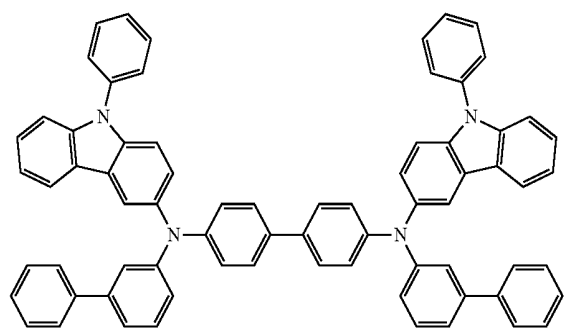
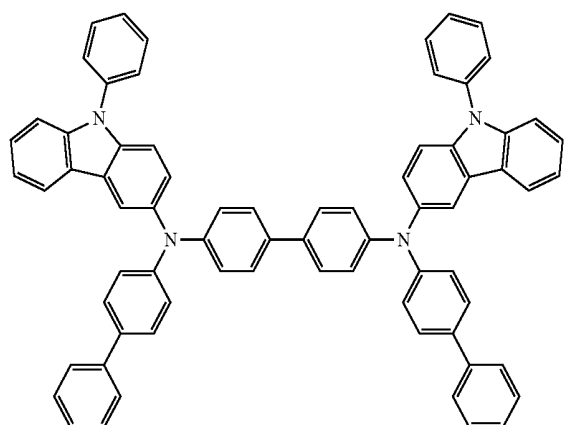


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125

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A thickness of the hole transport region may be in a range of about 100 Å to about 10,000 Å, for example, about 100 Å to about 1,000 Å. When the hole transport region includes at least one of a hole injection layer and a hole transport layer, a thickness of the hole injection layer may be in a range of about 100 Å to about 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. While not wishing to be bound by theory, it is understood that when the thickness values 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.

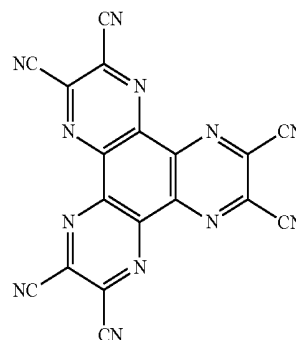
The hole transport region may further include, in addition to these materials, a charge-generation material for the improvement of conductive properties. The charge-generation material may be homogeneously or non-homogeneously dispersed in the hole transport region.

The charge-generation material may be, for example, a p-dopant. The p-dopant may be one selected from a quinone

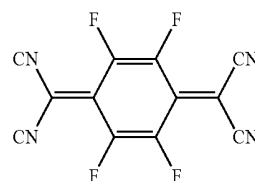
126

derivative, a metal oxide, and a cyano group-containing compound, but embodiments are not limited thereto. Non-limiting examples of the p-dopant are a quinone derivative, such as tetracyanoquinonedimethane (TCNQ) or 2,3,5,6-tetrafluoro-tetracyano-1,4-benzoquinonedimethane (F4-TCNQ); a metal oxide, such as a tungsten oxide or a molybdenum oxide; and a cyano group-containing compound, such as Compound HT-D1 below, but are not limited thereto:

Compound HT-D1



F4-TCNQ



The hole transport region may include a buffer layer.

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.

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

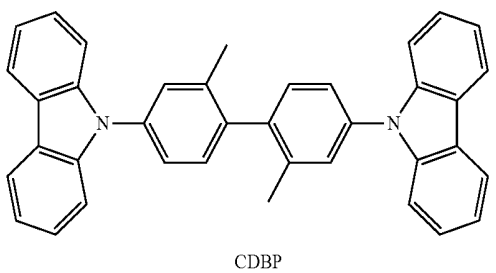
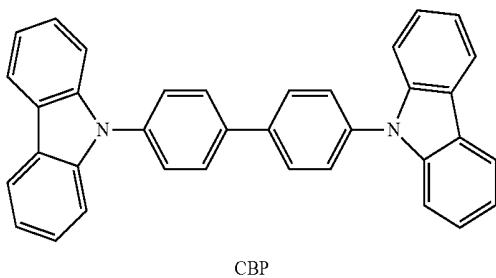
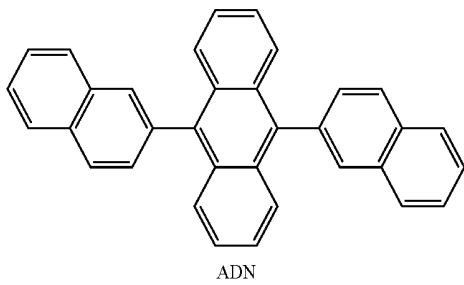
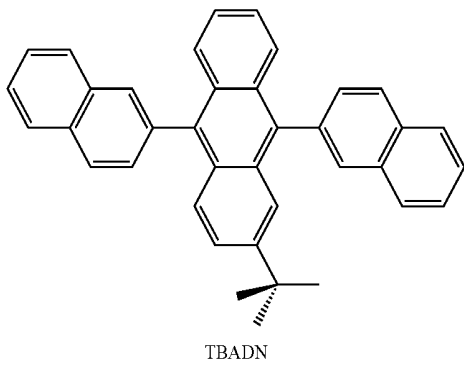
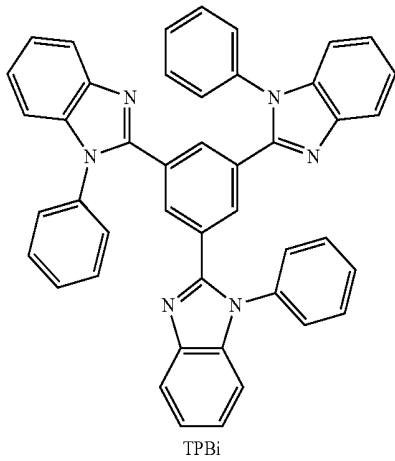
Meanwhile, when the hole transport region includes an electron blocking layer, a material for the electron blocking layer may be selected from materials for the hole transport region described above and materials for a host to be explained later.

However, the material for the electron blocking layer is not limited thereto. For example, when the hole transport region includes an electron blocking layer, a material for the electron blocking layer may be mCP, which will be explained later.

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

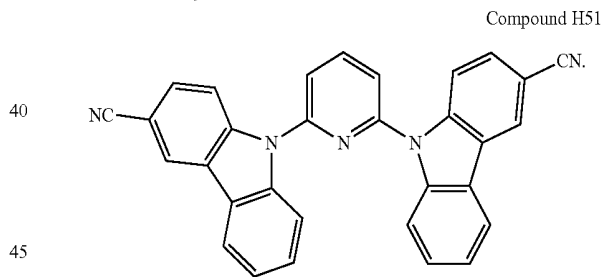
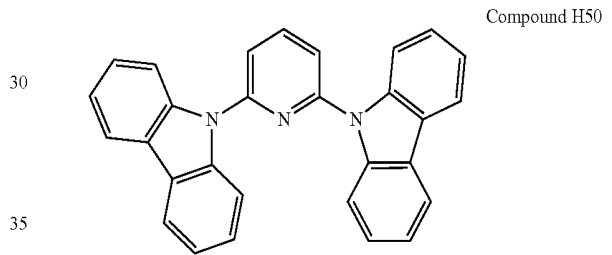
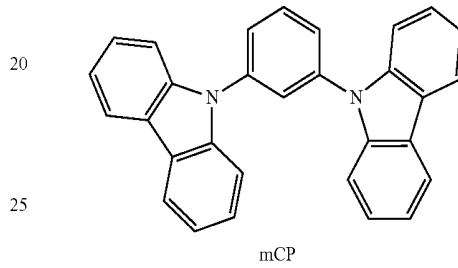
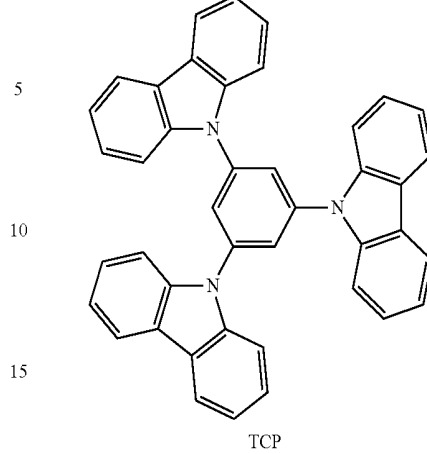
The host may include at least one selected from TPBi, TBADN, ADN (also referred to as "DNA"), CBP, CDBP, TCP, mCP, Compound H50, and Compound H51:

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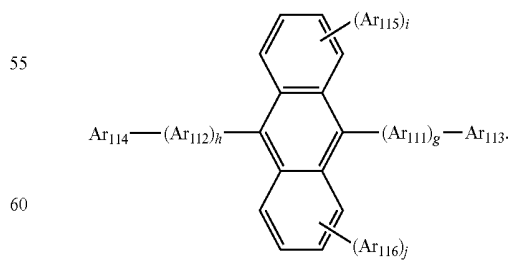
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In some embodiments, the host may further include a compound represented by Formula 301:

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Formula 301



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wherein, in Formula 301, Ar₁₁₁ and Ar₁₁₂ may be each independently selected from a phenylene group, a naphthylene group, a phenanthrylene group, and a pyrenylene group; and

129

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

Ar₁₁₃ to Ar₁₁₆ in Formula 301 may be each independently selected from

a C₁-C₁₀ alkyl group, a phenyl group, a naphthyl group, a phenanthrenyl group, and a pyrenyl group; and

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

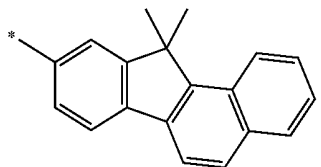
g, h, i, and j in Formula 301 may be each independently an integer selected from 0 to 4, for example, 0, 1, or 2.

Ar₁₁₃ to Ar₁₁₆ in Formula 301 may be each independently selected from

a C₁-C₁₀ alkyl group substituted with at least one selected from a phenyl group, a naphthyl group, and an anthracenyl group;

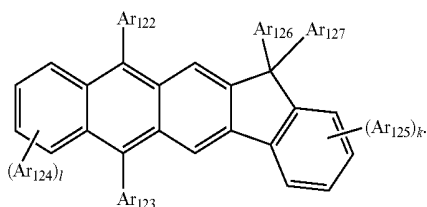
a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, and a fluorenyl group;

a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, and a fluorenyl group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, and a fluorenyl group; and



but embodiments are not limited thereto.

In some embodiments, the host may include a compound represented by Formula 302:



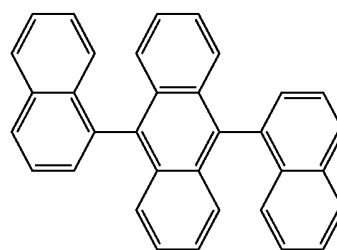
Ar₁₂₂ to Ar₁₂₅ in Formula 302 may be the same as described herein in connection with Ar₁₁₃ in Formula 301.

Ar₁₂₆ and Ar₁₂₇ in Formula 302 may be each independently a C₁-C₁₀ alkyl group, e.g., a methyl group, an ethyl group, or a propyl group.

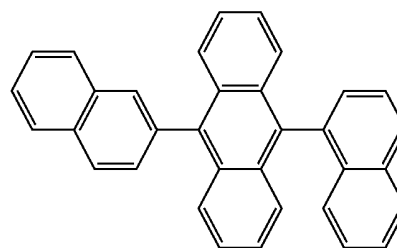
k and l in Formula 302 may be each independently an integer selected from 0 to 4. In some embodiments, k and l may each be 0, 1, or 2.

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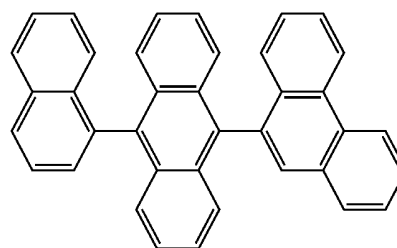
In some embodiments, the compound represented by Formula 301 and the compound represented by Formula 302 may include Compounds HT1 to HT42, but embodiments are not limited thereto:



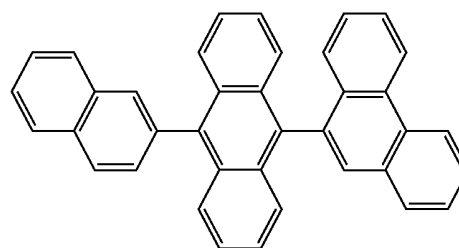
H1



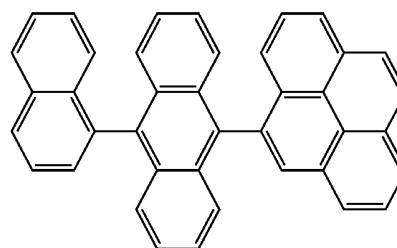
H2



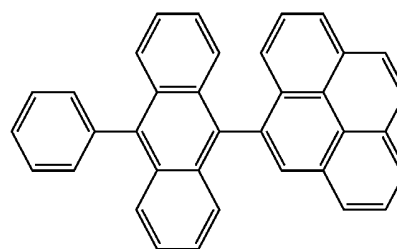
H3



H4



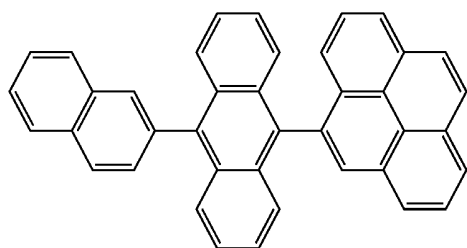
H5



H6

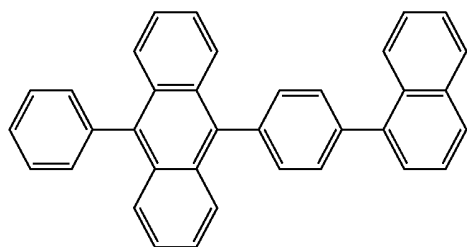
Formula 302

131
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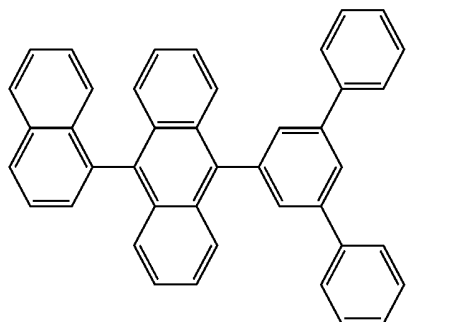
H7

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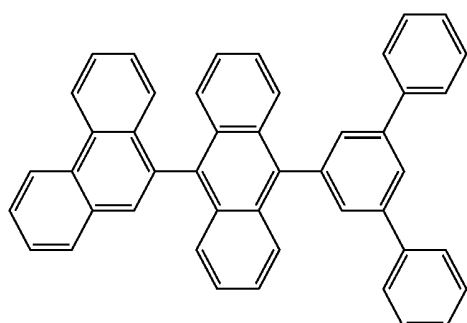
H8

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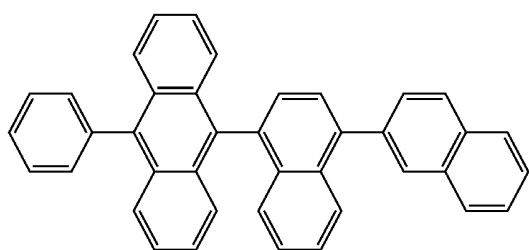
H9

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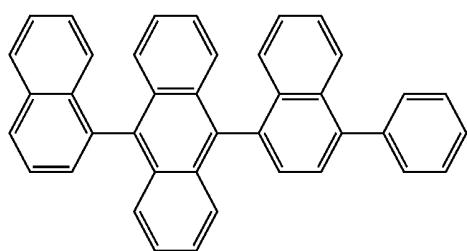
H10

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H11

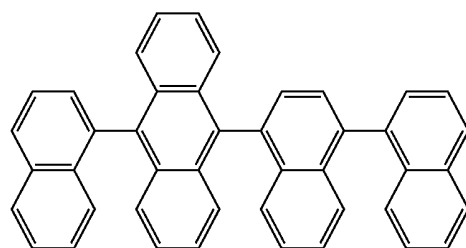
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H12

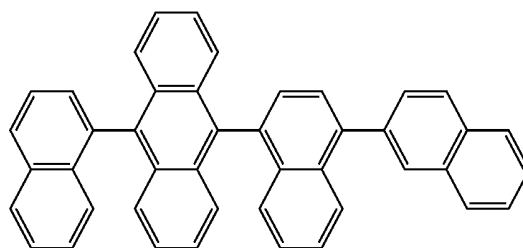
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132
-continued



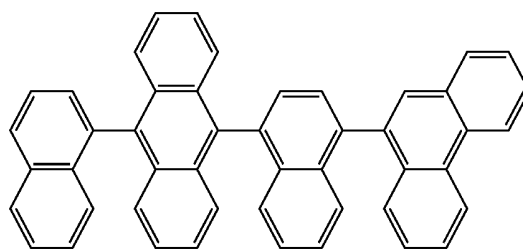
H13

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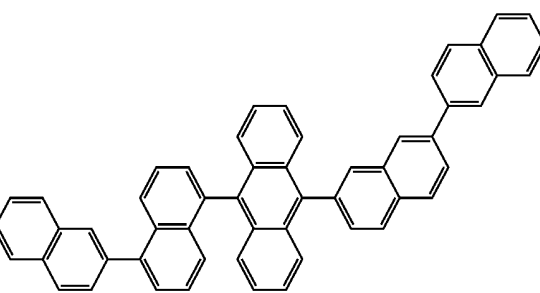
H14

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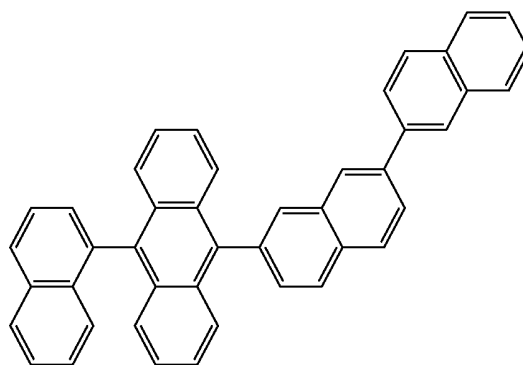
H15

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H16

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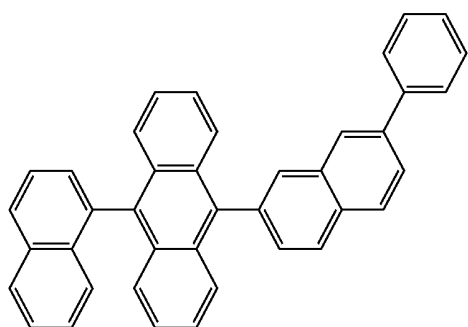
H17

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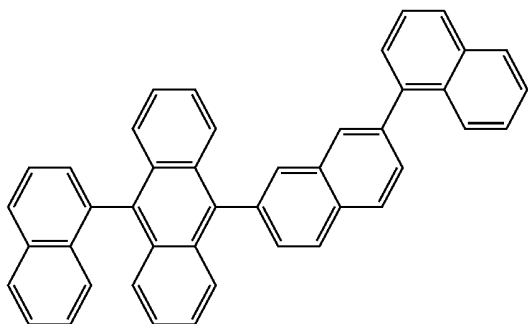
133
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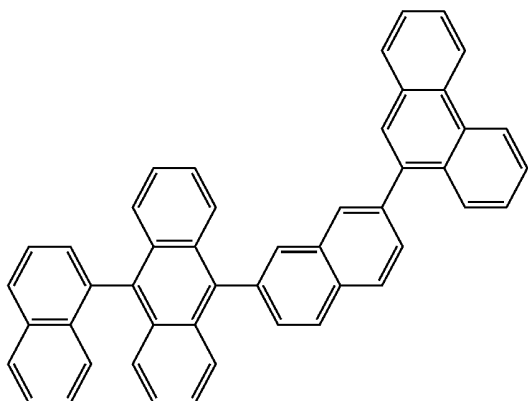
H19 15



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H20

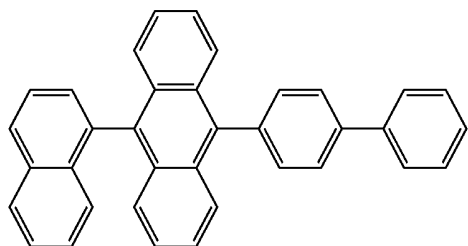


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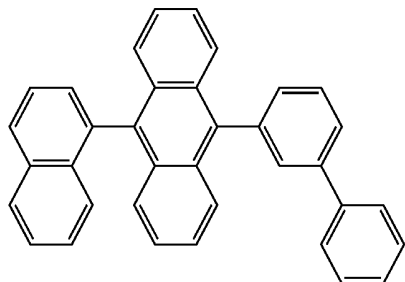
H21



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H22

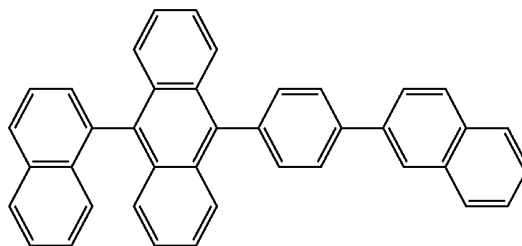


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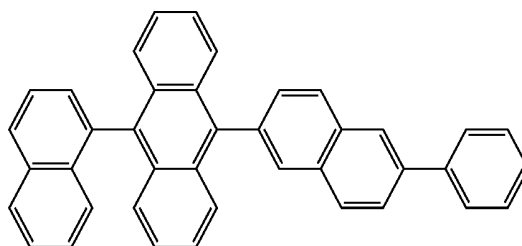


H23

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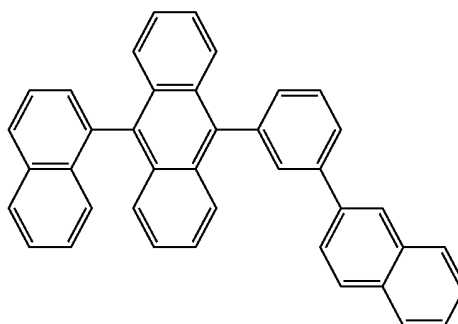
H24



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H25

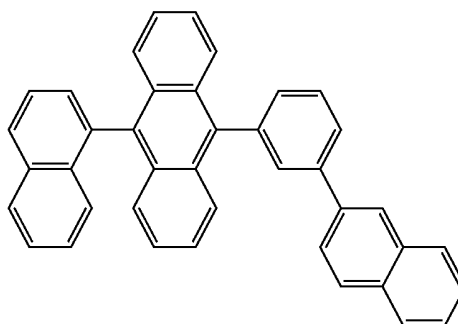


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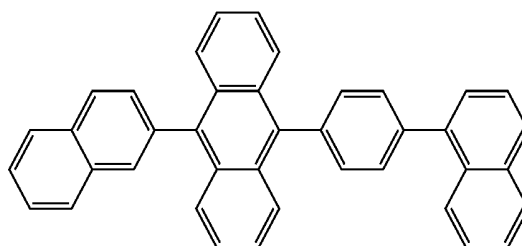
H26



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H27



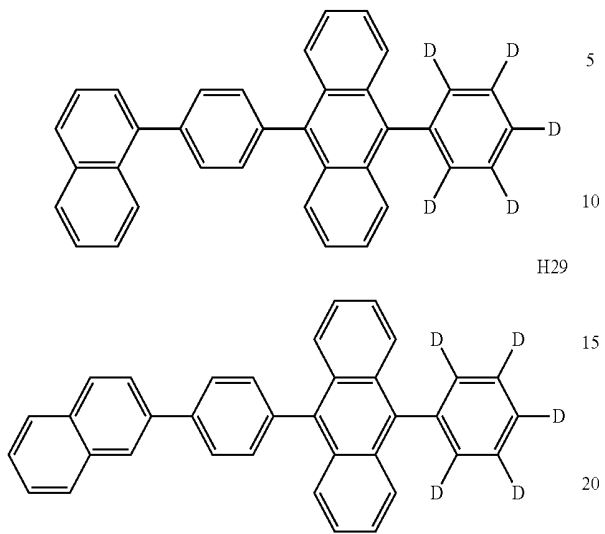
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135
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H28



H29

H30

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H31

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H32

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H33

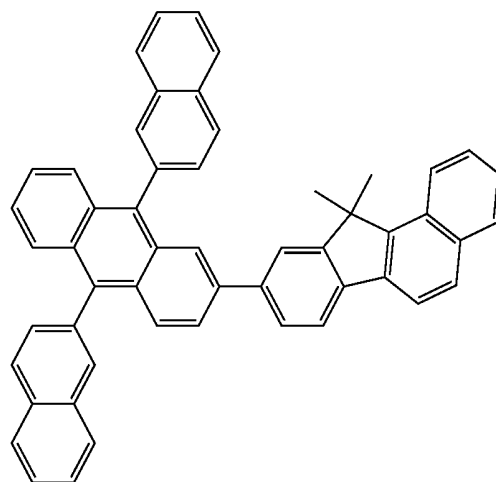
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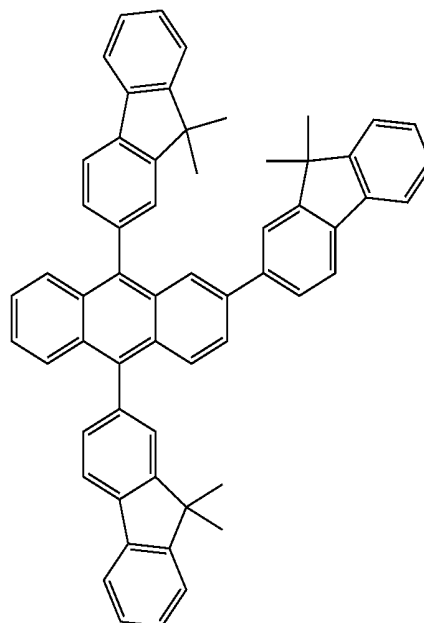
136
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H34

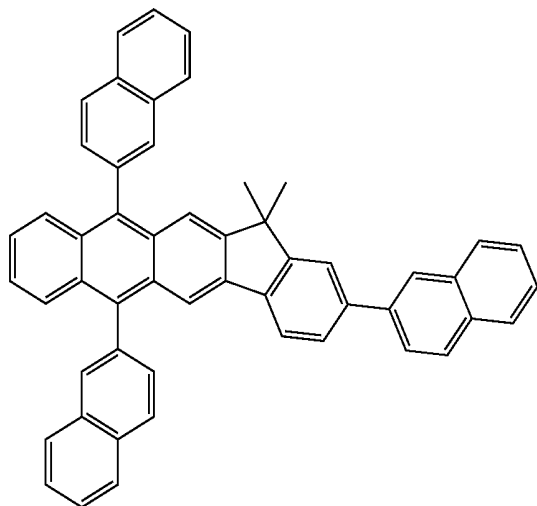
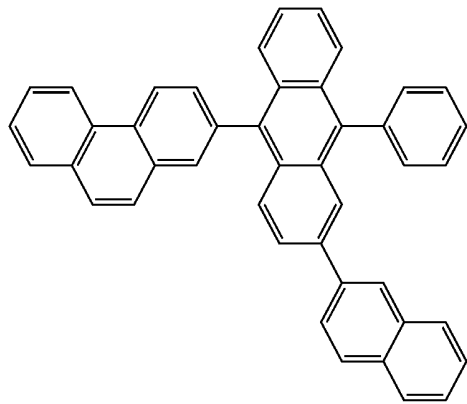
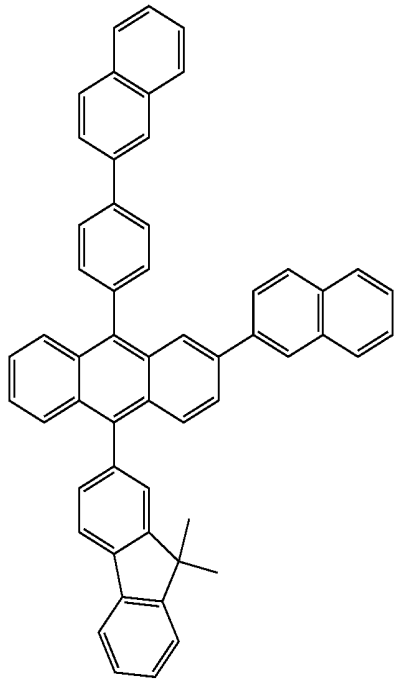


H35

H36

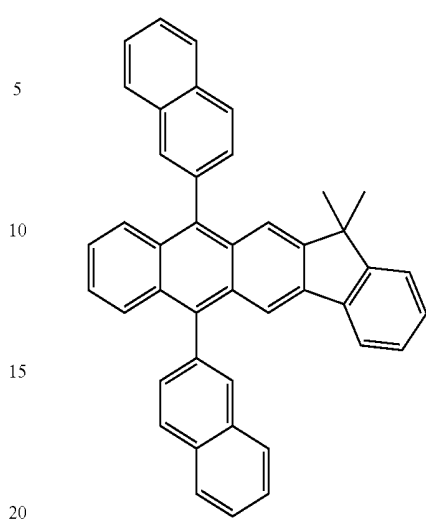


137
-continued



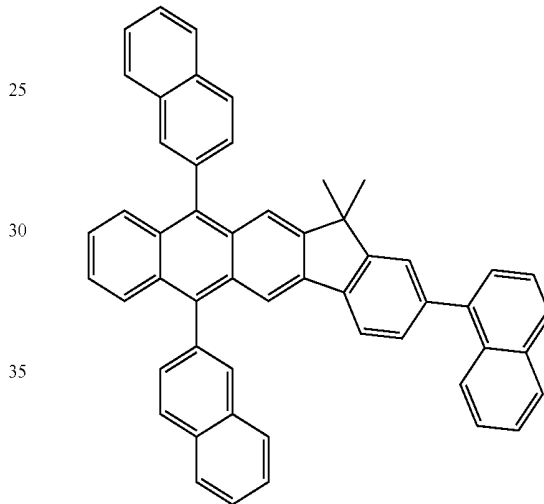
138
-continued

H37



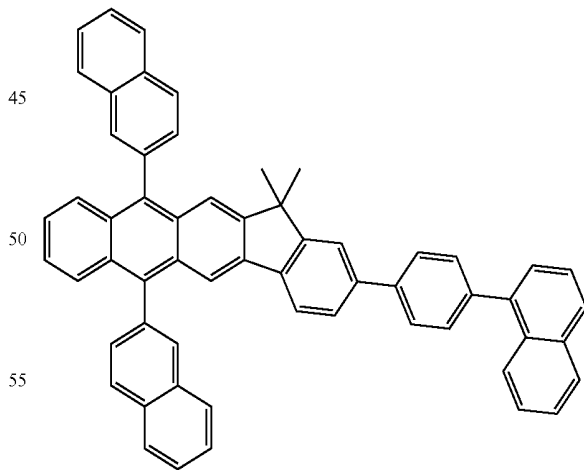
H40

H38



H41

H39



H42

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

139

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.

A thickness of the emission layer may be in a range of about 100 Å to about 1,000 Å, for example, about 200 Å to about 600 Å. While not wishing to be bound by theory, it is understood that when the thickness of the emission layer is within this range, excellent light-emission characteristics may be obtained without a substantial increase in driving voltage.

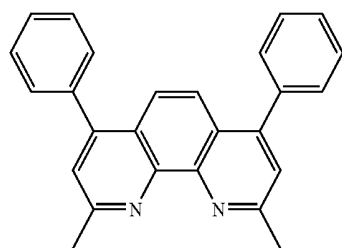
Then, an electron transport region may be disposed on the emission layer.

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

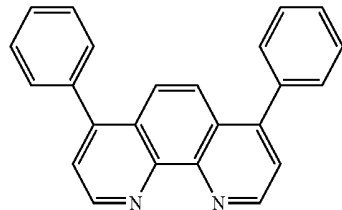
For example, the electron transport region may have a structure of hole blocking layer/electron transport layer/electron injection layer or a structure of electron transport layer/electron injection layer, but the structure of the electron transport region is not limited thereto. The electron transport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

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.

When the electron transport region includes a hole blocking layer, the hole blocking layer may include, for example, at least one of BCP, Bphen, and BA1q but is not limited thereto:



BCP

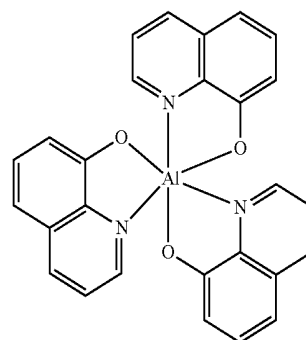
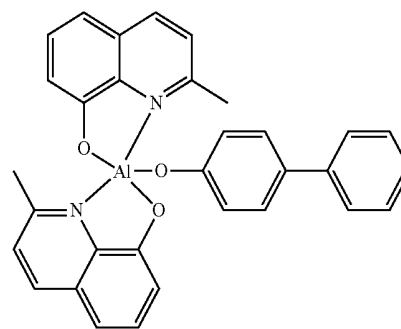


Bphen

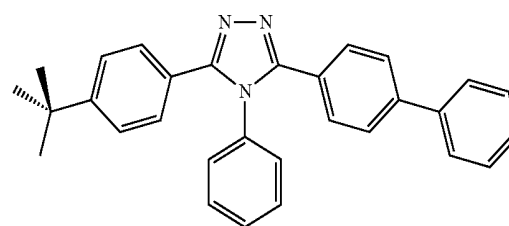
A thickness of the hole blocking layer may be in a range of about 20 Å to about 1,000 Å, for example, about 30 Å to about 300 Å. While not wishing to be bound by theory, it is understood that when the thickness of the hole blocking layer is within these ranges, the hole blocking layer may have excellent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

The electron transport layer may further include at least one selected from BCP, Bphen, Alq₃, BA1q, TAZ, and NTAZ:

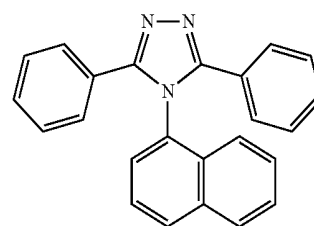
140

Alq₃

BA1q



TAZ



NTAZ

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

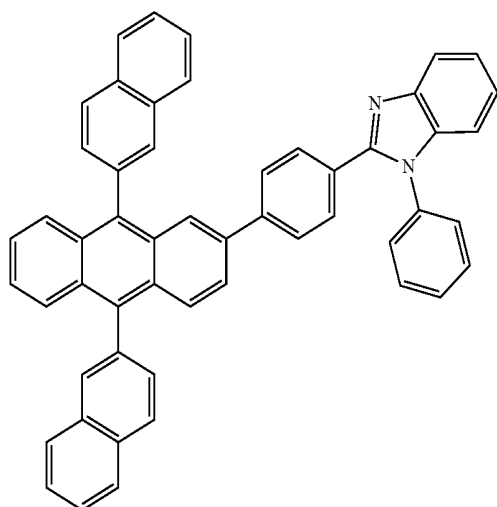
141

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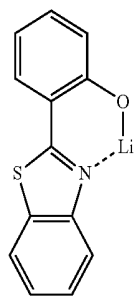
ET-D2

ET1



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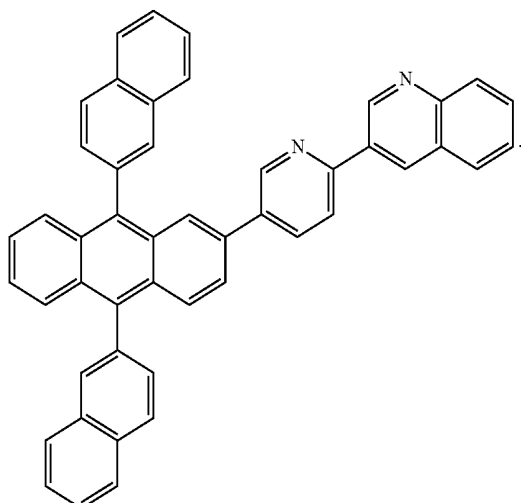


15 The electron transport region may include an electron injection layer that promotes flow of electrons from the second electrode **19** thereto.

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

20 A thickness of the electron injection layer may be in a range of about 1 Å to about 100 Å, for example, about 3 Å to about 90 Å. While not wishing to be bound by theory, it is understood that 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.

ET2



25 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**.

40 Hereinbefore, the organic light-emitting device has been described with reference to the FIGURE, but is not limited thereto.

Hereinbefore, the organic light-emitting device has been described with reference to the FIGURE, but is not limited thereto.

45 According to an aspect of another embodiment, there is provided a composition for diagnosing that includes at least one organometallic compound represented by Formula 1.

50 Since the organometallic compound represented by Formula 1 may provide high emission efficiency, the diagnostic efficiency of the composition for diagnosing that includes the organometallic compound represented by Formula 1 may be excellent.

The composition for diagnosing may be used in various manners, such as in a diagnostic kit, a diagnostic reagent, a biosensor, or a biomarker.

55 The term “C₁-C₆₀ alkyl group” as used herein refers to a linear or branched aliphatic saturated hydrocarbon monovalent group having 1 to 60 carbon atoms, and examples thereof include a methyl group, an ethyl group, a propyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, a pentyl group, an iso-amyl group, and a hexyl group. The term “C₁-C₆₀ alkylene group” as used herein refers to a divalent group having the same structure as the C₁-C₆₀ alkyl group.

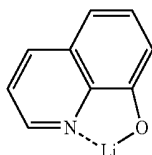
65 The term “C₁-C₆₀ alkoxy group” as used herein refers to a monovalent group represented by —OA₁₀₁ (wherein A₁₀₁

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

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

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



is the C₁-C₆₀ alkyl group), and examples thereof include a methoxy group, an ethoxy group, and an iso-propyloxy (iso-propoxy) group.

The term "C₂-C₆₀ alkenyl group" as used herein refers to a group formed by including at least one carbon-carbon double bond in the middle or at the terminal of the C₂-C₆₀ alkyl group, and detailed examples thereof include an ethenyl group, a propenyl group, and a butenyl group. The term "C₂-C₆₀ alkenylene group" as used herein refers to a divalent group having the same structure as the C₂-C₆₀ alkenyl group.

The term "C₂-C₆₀ alkynyl group" as used herein refers to a group formed by including at least one carbon-carbon triple bond in the middle or at the terminal of the C₂-C₆₀ alkyl group, and detailed examples thereof include an ethynyl group and a propenyl group. The term "C₂-C₆₀ alkynylene group" as used herein refers to a divalent group having the same structure as the C₂-C₆₀ alkynyl group.

The term "C₃-C₁₀ cycloalkyl group" as used herein refers to a monovalent saturated hydrocarbon monocyclic group having 3 to 10 carbon atoms, and non-limiting examples thereof include a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. The term "C₃-C₁₀ cycloalkylene group," as used herein, refers to a divalent group having the same structure as the C₃-C₁₀ cycloalkyl group.

The term "C₁-C₁₀ heterocycloalkyl group" as used herein refers to a monovalent saturated monocyclic group having at least one heteroatom selected from N, O, P, Si, and S as a ring-forming atom and 1 to 10 carbon atoms, and non-limiting examples thereof include a tetrahydrofuranlyl group and a tetrahydrothiophenyl group. The term "C₁-C₁₀ heterocycloalkylene group" as used herein refers to a divalent group having the same structure as the C₁-C₁₀ heterocycloalkyl group.

The term "C₃-C₁₀ cycloalkenyl group" as used herein refers to a monovalent monocyclic group that has 3 to 10 carbon atoms and at least one carbon-carbon double bond in the ring thereof and which is not aromatic. Non-limiting examples thereof include a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. The term "C₃-C₁₀ cycloalkenylene group" as used herein refers to a divalent group having the same structure as the C₃-C₁₀ cycloalkenyl group.

The term "C₁-C₁₀ heterocycloalkenyl group" as used herein refers to a monovalent monocyclic group that has at least one heteroatom selected from N, O, P, Si, and S as a ring-forming atom, 1 to 10 carbon atoms, and at least one carbon-carbon double bond in its ring. Non-limiting examples of the C₁-C₁₀ heterocycloalkenyl group include a 2,3-dihydrofuranlyl group and a 2,3-dihydrothiophenyl group. The term "C₁-C₁₀ heterocycloalkenylene group," as used herein, refers to a divalent group having the same structure as the C₁-C₁₀ heterocycloalkenyl group.

The term "C₆-C₆₀ aryl group" as used herein refers to a monovalent group having an aromatic system having 6 to 60 carbon atoms, and the term "C₆-C₆₀ arylene group" as used herein refers to a divalent group having an aromatic system having 6 to 60 carbon atoms. Non-limiting examples of the C₆-C₆₀ aryl group include 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.

The term "C₁-C₆₀ heteroaryl group" as used herein refers to a monovalent group having a cyclic aromatic system that has at least one heteroatom selected from N, O, P, Si, and S

as a ring-forming atom, and 1 to 60 carbon atoms. The term "C₁-C₆₀ heteroarylene group" as used herein refers to a divalent group having an aromatic system that has at least one heteroatom selected from N, O, P, and S as a ring-forming atom, and 1 to 60 carbon atoms. Non-limiting examples of the C₁-C₆₀ heteroaryl group include a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, and an isoquinolinyl group. When the C₁-C₆₀ heteroaryl group and the C₁-C₆₀ heteroarylene group each include two or more rings, the rings may be fused to each other.

The term "C₆-C₆₀ aryloxy group" as used herein indicates —OA₁₀₂ (wherein A₁₀₂ is the C₆-C₆₀ aryl group), and a C₆-C₆₀ arylthio group used herein indicates —SA₁₀₃ (wherein A₁₀₃ is the C₆-C₆₀ aryl group).

The term "monovalent non-aromatic condensed polycyclic group" as used herein refers to a monovalent group (e.g., having 8 to 60 carbon atoms) that has two or more rings condensed to each other, only carbon atoms as a ring-forming atom, and which is non-aromatic in the entire molecular structure. Examples of the monovalent non-aromatic condensed polycyclic group include a fluorenyl group. The term "divalent non-aromatic condensed polycyclic group" as used herein refers to a divalent group having the same structure as the monovalent non-aromatic condensed polycyclic group.

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

At least one of substituents of the substituted C₅-C₃₀ carbocyclic group, substituted C₂-C₃₀ heterocyclic group, substituted C₁-C₆₀ alkyl group, substituted C₂-C₆₀ alkenyl group, substituted C₂-C₆₀ alkynyl group, substituted C₁-C₆₀ alkoxy group, substituted C₃-C₁₀ cycloalkyl group, substituted C₁-C₁₀ heterocycloalkyl group, substituted C₃-C₁₀ cycloalkenyl group, substituted C₁-C₁₀ heterocycloalkenyl group, substituted C₆-C₆₀ aryl group, substituted C₆-C₆₀ aryloxy group, substituted C₆-C₆₀ arylthio group, substituted C₁-C₆₀ heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from:

deuterium, —F, —Cl, —Br, —I, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, 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 deuterium, —F, —Cl, —Br, —I, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, 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

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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), —B(Q₁₆)(Q₁₇), and —P(=O)(Q₁₈)(Q₁₉);

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 deuterium, —F, —Cl, —Br, —I, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, 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), —B(Q₂₆)(Q₂₇), and —P(=O)(Q₂₈)(Q₂₉); and

—N(Q₃₁)(Q₃₂), —Si(Q₃₃)(Q₃₄)(Q₃₅), —B(Q₃₆)(Q₃₇), and —P(=O)(Q₃₈)(Q₃₉),

wherein Q₁ to Q₆, Q₁₁ to Q₁₉, Q₂₁ to Q₂₉, and Q₃₁ to Q₃₉ may be each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid 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 aryl group substituted with at least one selected from a C₁-C₆₀ alkyl group and 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.

When a group containing a specified number of carbon atoms is substituted with any of the groups listed in the preceding paragraphs, the number of carbon atoms in the resulting "substituted" group is defined as the sum of the carbon atoms contained in the original (unsubstituted) group and the carbon atoms (if any) contained in the substituent. For example, when the term "substituted C₁-C₆₀ alkyl" refers to a C₁-C₆₀ alkyl group substituted with C₆-C₆₀ aryl substituted alkyl group is C₇-C₁₂₀.

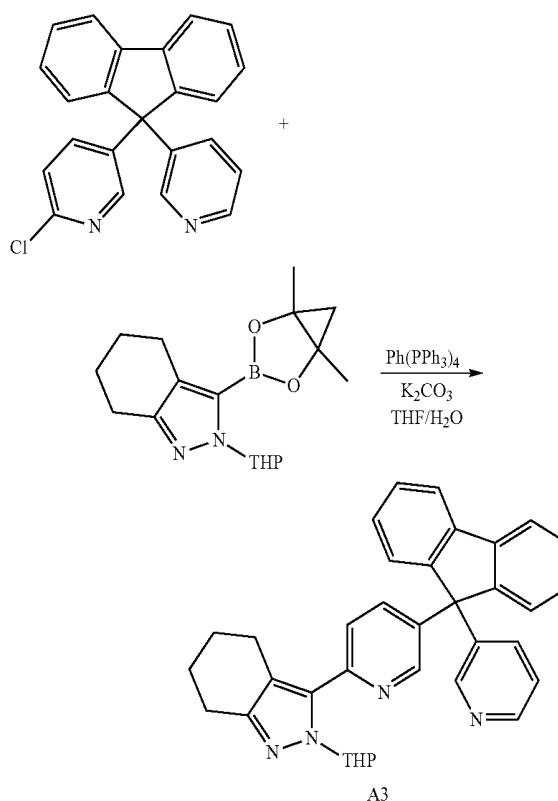
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Hereinafter, a compound and an organic light-emitting device according to embodiments are described in detail with reference to Synthesis Example and Examples. However, the organic light-emitting device is not limited thereto. The wording "B was used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

EXAMPLE

Synthesis Example 1: Synthesis of Compound 33

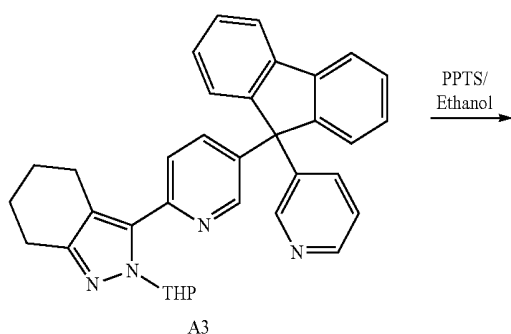
Synthesis of Intermediate A3



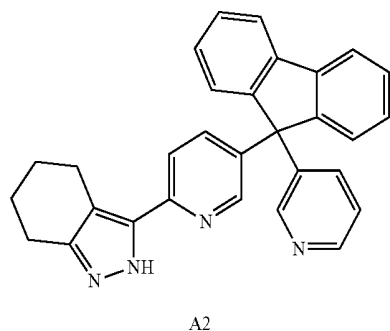
5 grams (g) (14.1 millimoles, mmol) of 2-chloro-5-(9-(pyridin-3-yl)-9H-fluoren-9-yl)pyridine, 5.35 g (16.9 mmol) of 3-(1,5-dimethyl-2,4-dioxo-3-borabicyclo[3.1.0]hexan-3-yl)-2-(tetrahydro-2H-pyran-2-yl)-4,5,6,7-tetrahydro-2H-indazole, 1.14 g (1.0 mmol) of Pd(PPh₃)₄, and 3.89 g (28.2 mmol) of K₂CO₃ were mixed together with 60 milliliters (mL) of tetrahydrofuran (THF) and 30 mL of water (H₂O). The mixture was stirred at a temperature of about 75° C. for about 18 hours. The temperature was then lowered to room temperature, followed by filtering of the mixture. An organic layer was extracted from the resultant using methylene chloride (MC), and an anhydrous magnesium sulfate (MgSO₄) was added thereto to dry the organic layer. The resultant was filtered and a solvent in the obtained filtrate was removed under reduced pressure. The residual was purified by column chromatography using ethyl acetate (EA) and hexane at a ratio of 10:90 to obtain 5.03 g (81%) of Intermediate A3.

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Synthesis of Intermediate A2



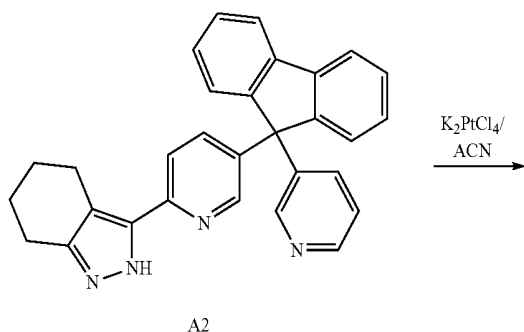
A3



A2

5.03 g (11.4 mmol) of Intermediate A3 and 1.20 g (5.7 mmol) of pyridinium p-toluenesulfonate (PPTS) were mixed together with 100 mL of ethanol. The mixture was stirred at a temperature of about 78° C. for about 12 hours. The temperature was then lowered to room temperature, followed by filtering of the mixture. An organic layer was extracted from the resultant using MC, and an anhydrous magnesium sulfate ($MgSO_4$) was added thereto to dry the organic layer. The resultant was filtered and a solvent in the obtained filtrate was removed under reduced pressure. The residual was purified by column chromatography using EA, hexane, and methanol at a ratio of 24:75:1 to obtain 3.17 g (75%) of Intermediate A2.

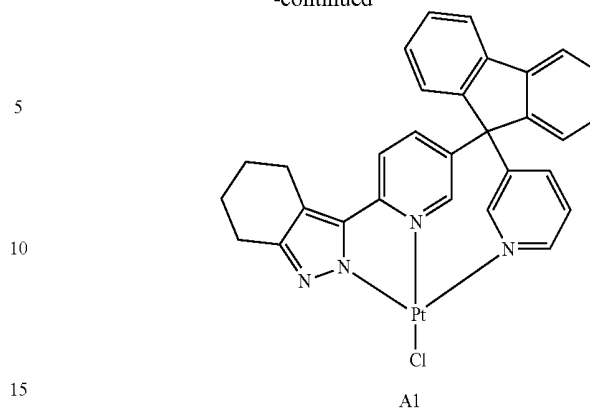
Synthesis of Intermediate A1



A2

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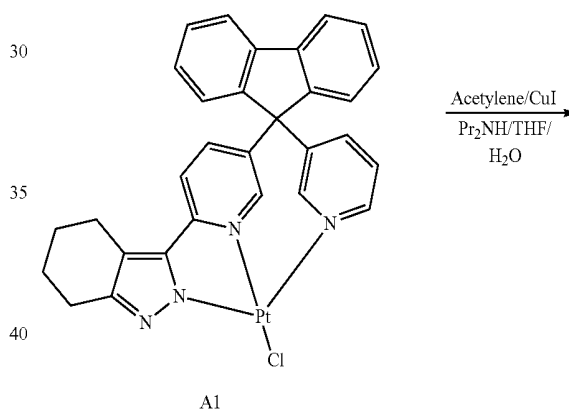
-continued



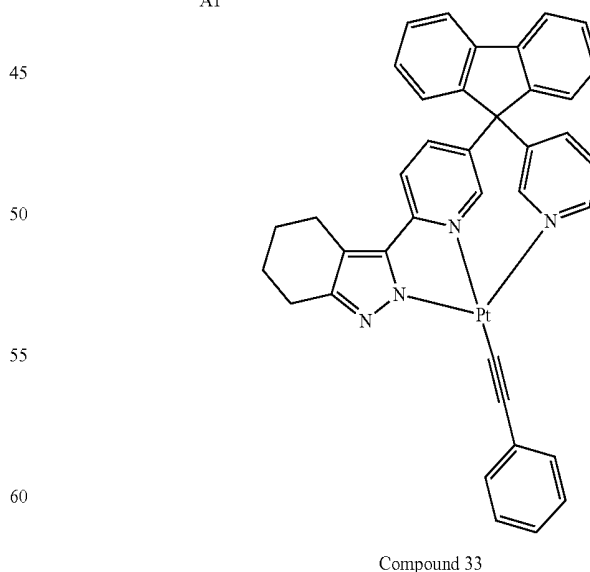
A1

3.1 g (7.04 mmol) of Intermediate A₂ and 2.92 g (7.04 mmol) of K_2PtCl_4 were mixed together with 60 mL of acetonitrile (ACN). The mixture was stirred at a temperature of about 100° C. for about 24 hours to carry out the reaction. Thereafter, the temperature was lowered. The mixture obtained therefrom was filtered to obtain a solid. The solid was thoroughly washed with methanol and water and dried to obtain 2.83 g (60%) of Intermediate A1.

Synthesis of Compound 33



A1

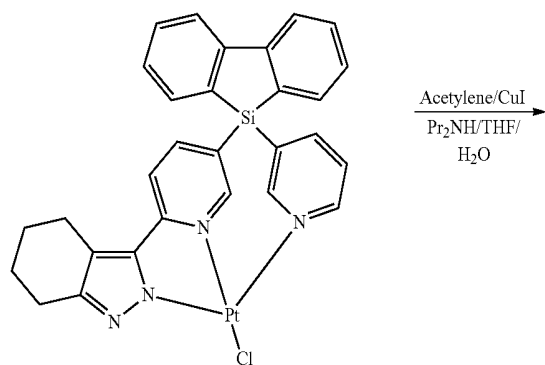


Compound 33

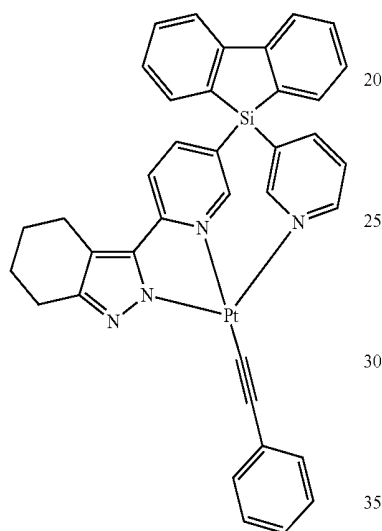
2.8 g (4.18 mmol) of Intermediate A1, 0.51 g (5.01 mmol) of acetylene, 0.04 g (0.21 mmol) of CuI, and 1.27 g (12.54 mmol) of diisopropylamine were mixed together with 40 mL

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Synthesis of Compound 34



B1



Compound 34

1.12 g (31%) of Compound 34 was obtained in the same manner as Compound 33 in Synthesis Example 1, except that 3.30 g (4.81 mmol) of Intermediate B1 was used instead of Intermediate A1. The identity of the obtained compound was confirmed by using mass spectroscopy and HPLC analysis.

HRMS(MALDI) calcd for $\text{C}_{37}\text{H}_{28}\text{N}_4\text{PtSi}$: m/z 751.8280, Found: 751.8278.

Example 1

An ITO glass substrate was cut to a size of 50 millimeters (mm) \times 50 mm \times 0.5 mm. Then the glass substrate was sonicated in acetone iso-propyl alcohol and pure water for about 15 minutes in each solvent, and cleaned by exposure to ultraviolet rays with ozone for 30 minutes.

Then, a hole injection layer was formed on an ITO electrode (anode) that is on the glass substrate by vacuum-depositing m-MTDATA at a deposition rate of about 1 Angstrom per second ($\text{\AA}/\text{sec}$) to have a thickness of about 600 \AA . A hole transport layer was formed on the hole injection layer by vacuum-depositing α -NPD at a deposition rate of about 1 $\text{\AA}/\text{sec}$ to have a thickness of about 250 Angstroms (\AA).

An emission layer was formed on the hole transport layer by co-depositing Compound 33 (dopant) and CBP (host) at a deposition rate of about 0.1 $\text{\AA}/\text{sec}$ and 1 $\text{\AA}/\text{sec}$, respectively, to have a thickness of about 400 \AA .

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A hole blocking layer was formed on the emission layer by vacuum-depositing BALq at a deposition rate of 1 $\text{\AA}/\text{sec}$ to have a thickness of about 50 \AA . The electron transport layer was formed on the hole blocking layer by vacuum-depositing Alq_3 to have a thickness of about 300 \AA . An electron injection layer was formed on the electron transport layer by vacuum-depositing LiF to have a thickness of about 10 \AA . A second electrode (cathode) was formed on the electron injection layer by vacuum-depositing Al to have a thickness of about 1,200 \AA . Accordingly, the manufacture of an organic light-emitting device was completed, in which the organic light-emitting device included a structure of ITO/m-MTDATA (600 \AA)/ α -NPD (250 \AA)/CBP+10% (Compound 33) (400 \AA)/BALq (50 \AA)/ Alq_3 (300 \AA)/LiF (10 \AA)/Al (1,200 \AA).

Examples 2 and Comparative Examples 1 and 2

An organic light-emitting device was manufactured in the same manner as in Example 1, except that the compounds listed in Table 2 were used instead of Compound 33 as a dopant in the formation of the emission layer.

Evaluation Example 1: Evaluation of Characteristics of Organic Light-Emitting Device

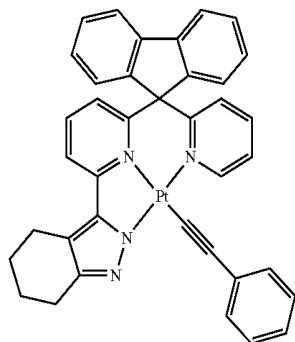
The driving voltage, emission efficiency, power efficiency, color-coordination, quantum efficiency, and lifespan (T_{95}) of the organic light-emitting devices manufactured in Examples 1 and 2 and Comparative Examples 1 and 2 were evaluated. The results thereof are shown in Table 2. A Keithley 2400 current voltmeter and a luminance meter (Minolta Cs-1000A) were used in the evaluation. The lifespan (T_{95}) refers to time required for the initial luminance of 6,000 nit of the organic light-emitting device to reduce by 95%.

TABLE 2

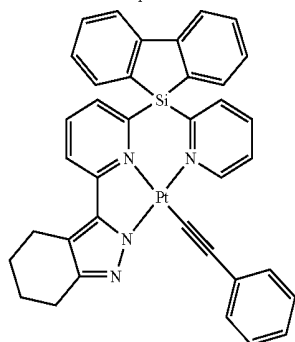
	Dopant	Driv-	Emis-	Power	Color		Quan-	Life-	
		ing	sion	Effi-	CIEx	CI Ey	tum		
		Vol-	Effi-	Effi-			effi-	span	
		tage	ciency	ciency			ciency	(hr)	
		(V)	(cd/A)	(lm/W)			(%)	(T_{95})	
50	Exam- ple 1	Com- pound 33	5.0	47.8	29.1	0.369	0.602	17.2	180
55	Exam- ple 2	Com- pound 34	5.2	45.2	28.0	0.363	0.598	16.5	185
	Compa- rative	Com- pound	6.9	20.1	13.4	0.390	0.623	8.3	63
60	Exam- ple 1	A							
	Compa- rative	Com- pound	6.8	25.2	15.1	0.386	0.635	9.2	50
65	Exam- ple 2	B							

TABLE 2-continued

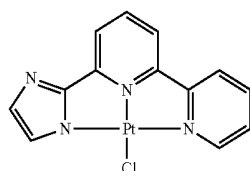
Dopant	Driving voltage (V)	Emission Efficiency (cd/A)	Power Efficiency (lm/W)	CIE _x	CIE _y	Quantum efficiency (%)	Lifespan (hr) (T ₉₅)
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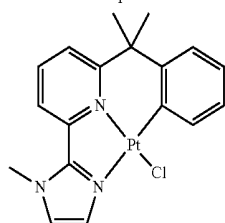
Compound 33



Compound 34



Compound A



Compound B

Referring to Table 2, it was found that the organic light-emitting devices manufactured in Examples 1 and 2 had excellent driving voltage, emission efficiency, power efficiency, color-coordination, quantum efficiency, and lifespan characteristics, as compared with the organic light-emitting devices of Comparative Examples 1 and 2.

The organometallic compound has excellent electric characteristics and thermal stability. Accordingly, an organic light-emitting device using the organometallic compound has a low driving voltage, high emission efficiency, high power efficiency, high color coordination, and excellent lifespan characteristics. Further, a composition for diagnosing including the organometallic compound may have high diagnostic efficiency, since the organometallic compound has excellent phosphorescent emission characteristics.

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

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

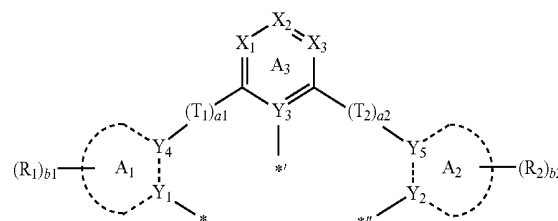
What is claimed is:

1. An organometallic compound represented by Formula 1:



Formula 1

Formula 2



wherein, in Formulae 1 and 2,

M is palladium, gold, or platinum,

L₁ is selected from tridentate ligands represented by Formula 2,

L₂ is selected from monodentate organic ligands, *', and *'' in Formula 2 each indicate a binding site to M in Formula 1,

Y₁ to Y₃ are each nitrogen,

Y₄ and Y₅ are each carbon,

Y₁ is bound to Y₄ via a single or double bond, Y₂ is bound to Y₅ via a single or double bond,

a bond between Y₁ and M and a bond between ligand L₂ and M are each a covalent bond, and a bond between Y₃ and M and a bond between Y₂ and M are each a coordinate bond,

T₁ is a group selected from a single bond, *—O—*', *—S—*', *—C(R₆)(R₇)—*', *—C(R₆)=*', *—C(R₆)—*', *—C(R₆)=C(R₇)—*', *—C(=O)—*', *—C(=S)—*', *—C≡C—*', *—N(R₆)—*', *—Si(R₆)(R₇)—*', and *—P(R₆)(R₇)—*', wherein * and *' in each of the foregoing groups independently indicate a binding site to a neighboring atom,

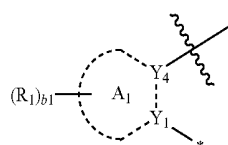
T₂ is a group selected from *—O—*', *—S—*', *—C(R₆)(R₇)—*', *—C(R₆)=*', *—C(R₆)—*', *—C(R₆)=C(R₇)—*', *—C(=O)—*', *—C(=S)—*', *—C≡C—*', *—N(R₆)—*', *—Si(R₆)(R₇)—*', and *—P(R₆)(R₇)—*', wherein * and *' in each of the foregoing groups independently indicate a binding site to a neighboring atom,

R₆ and R₇ are optionally bound to each other to form a substituted or unsubstituted C₅-C₃₀ carbocyclic group or a substituted or unsubstituted C₂-C₃₀ heterocyclic group,

a1 and a2 are each independently an integer selected from 1 to 3,

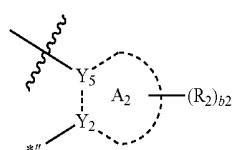
155

a moiety in Formula 2 represented by

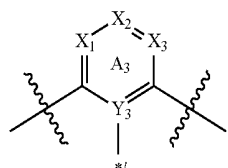


is represented by one of Formulae 3-32 to 3-34 and 3-48 to 3-50,

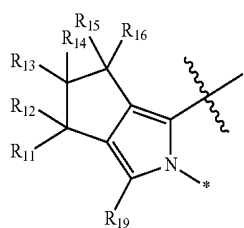
a moiety in Formula 2 represented by



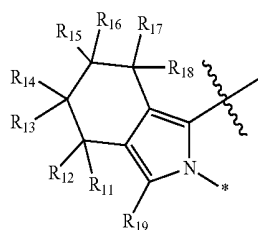
is represented by one of Formulae 4-1 to 4-53, and a moiety in Formula 2 represented by



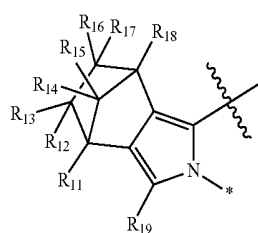
is represented by one of Formulae 5-1 to 5-48:



Formula 3-32



Formula 3-33

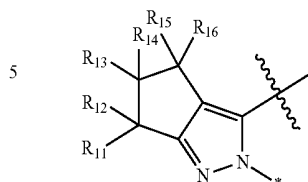


Formula 3-34

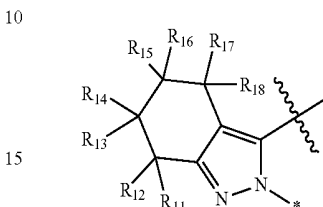
156

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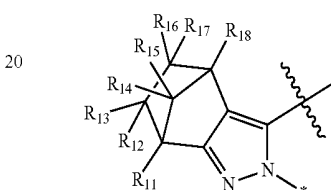
Formula 3-48



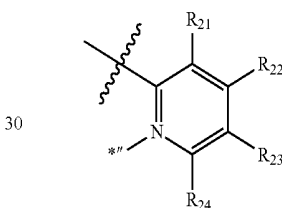
Formula 3-49



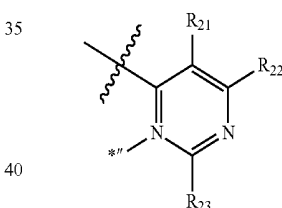
Formula 3-50



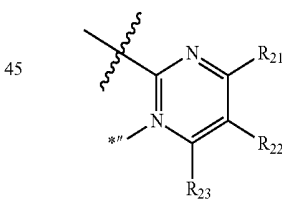
Formula 4-1



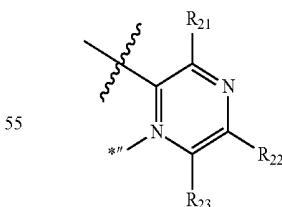
Formula 4-2



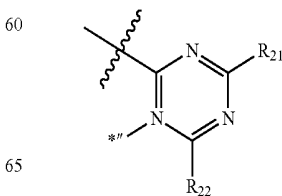
Formula 4-3



Formula 4-4



Formula 4-5

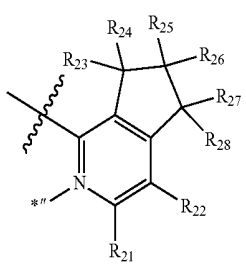
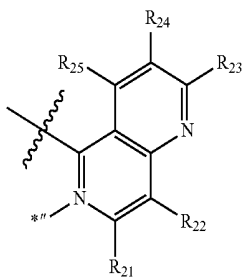
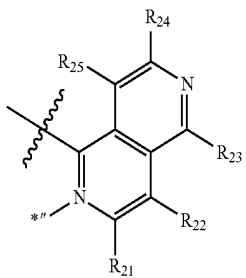
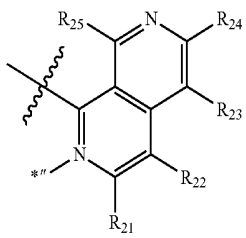
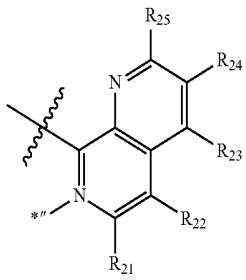
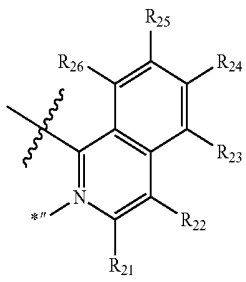


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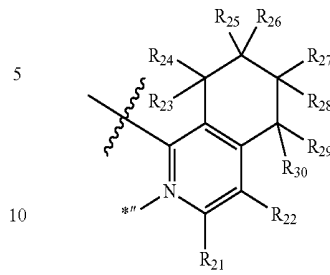
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157
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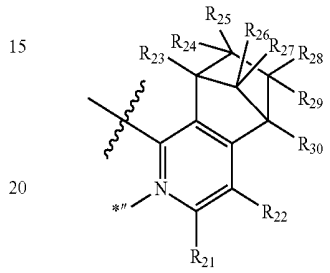
158
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Formula 4-6



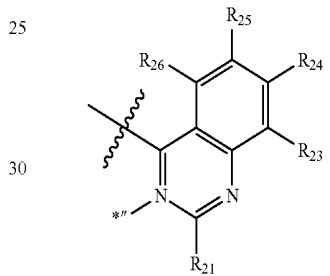
Formula 4-12

Formula 4-7



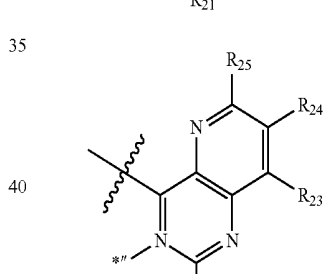
Formula 4-13

Formula 4-8



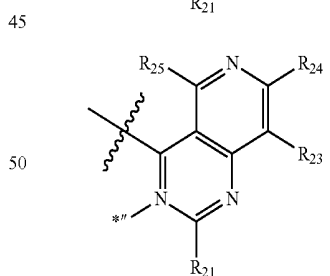
Formula 4-14

Formula 4-9



Formula 4-15

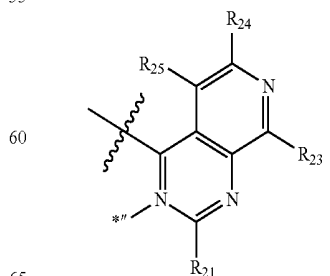
Formula 4-10



Formula 4-16

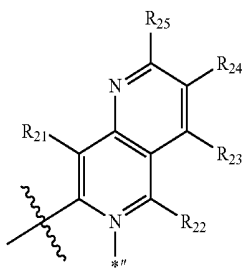
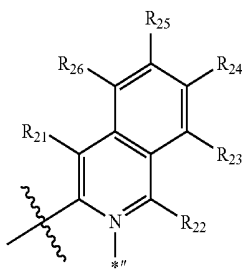
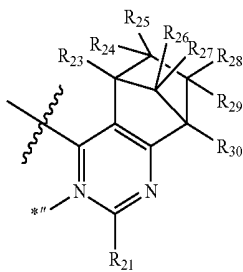
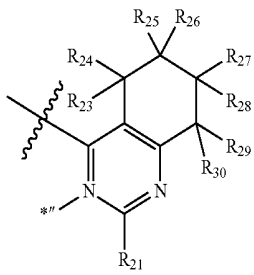
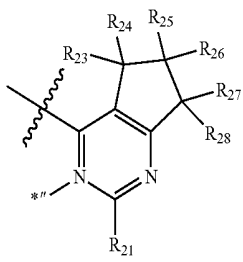
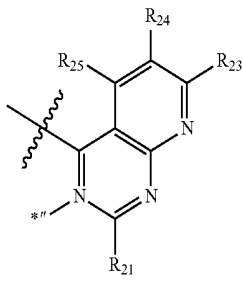
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Formula 4-11



Formula 4-17

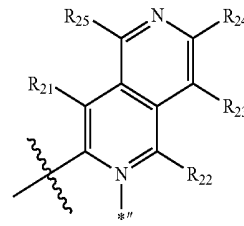
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160
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Formula 4-18

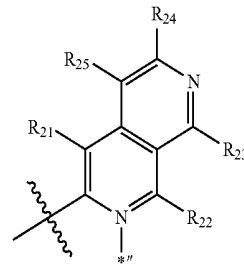
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Formula 4-19

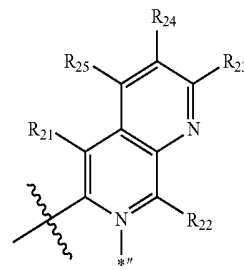
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Formula 4-20

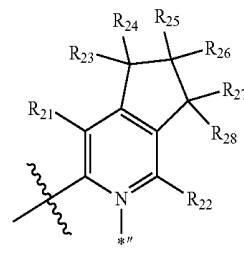
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Formula 4-21

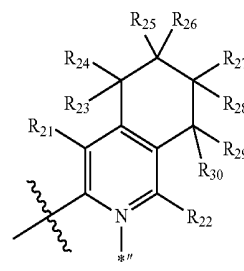
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Formula 4-22

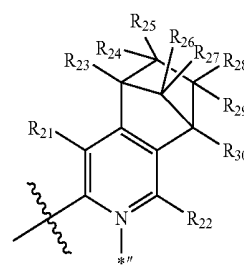
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Formula 4-23

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Formula 4-24

Formula 4-25

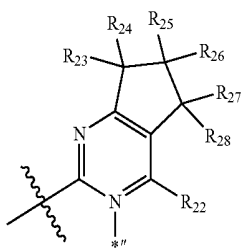
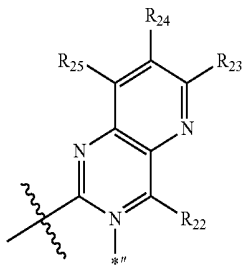
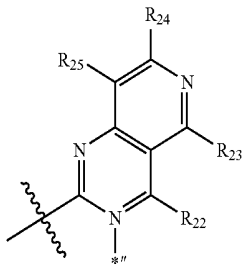
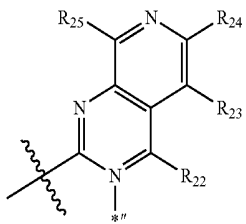
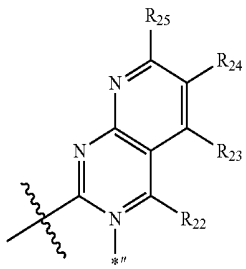
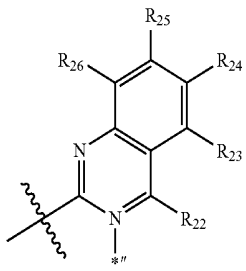
Formula 4-26

Formula 4-27

Formula 4-28

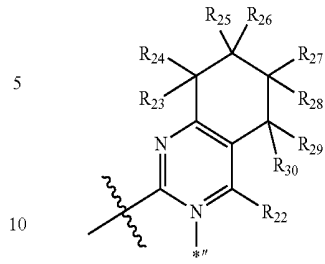
Formula 4-29

161
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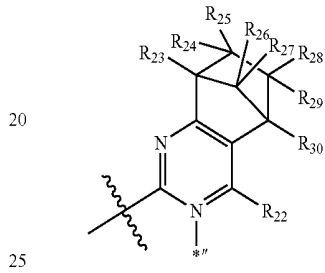


162
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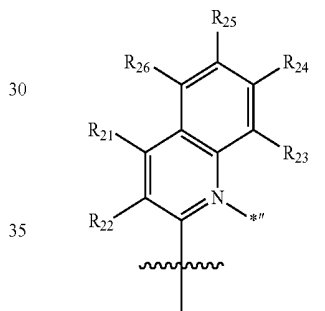
Formula 4-30



Formula 4-31



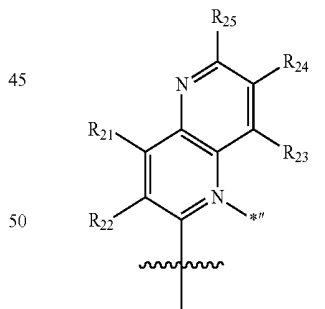
Formula 4-32



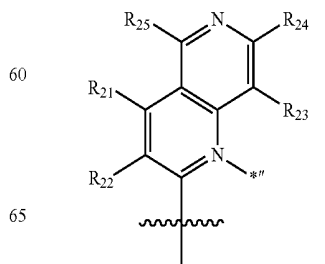
Formula 4-33



Formula 4-34



Formula 4-35



Formula 4-36

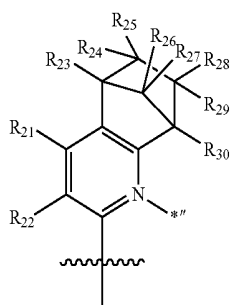
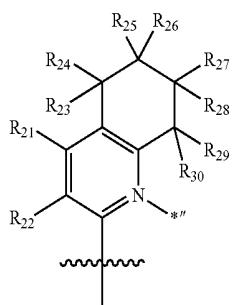
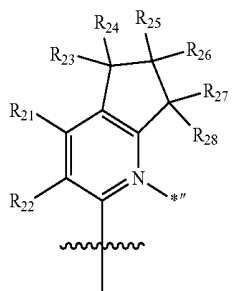
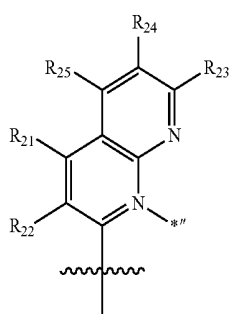
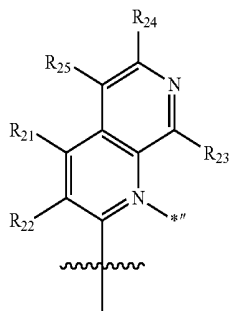
Formula 4-37

Formula 4-38

Formula 4-39

Formula 4-40

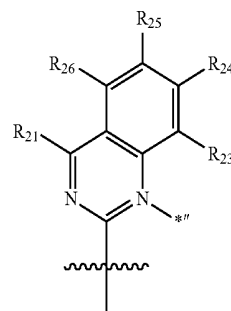
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164
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Formula 4-41

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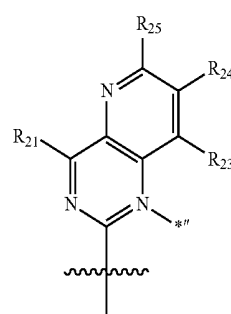


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Formula 4-42

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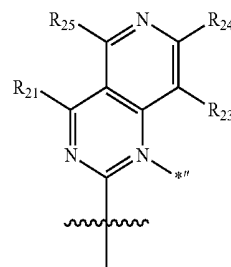


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Formula 4-43

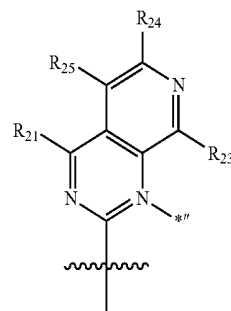
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Formula 4-44

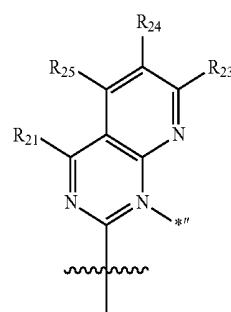
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Formula 4-45

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Formula 4-46

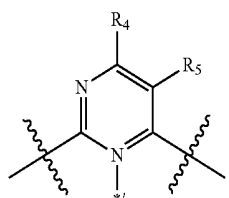
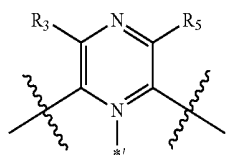
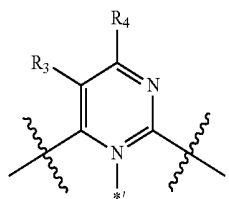
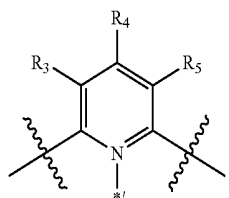
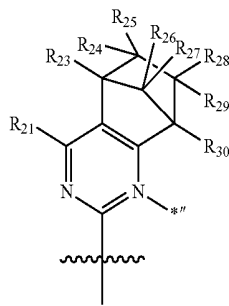
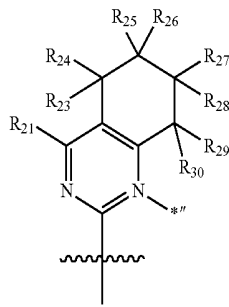
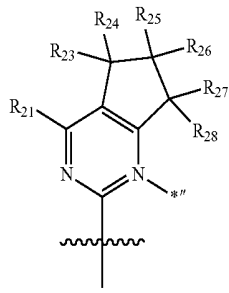
Formula 4-47

Formula 4-48

Formula 4-49

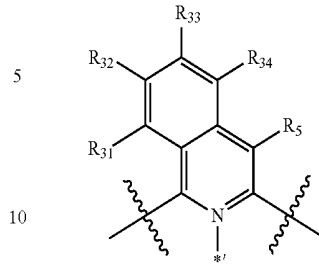
Formula 4-50

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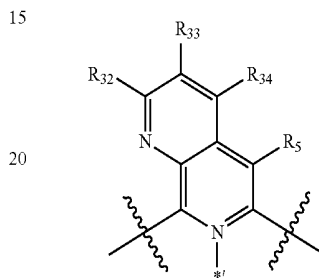


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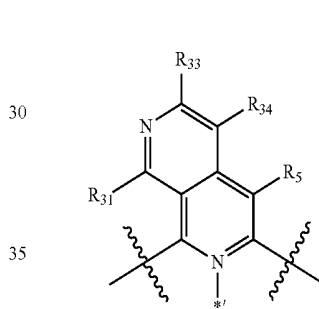
Formula 4-51



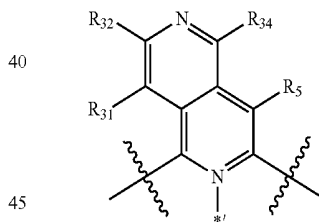
Formula 4-52



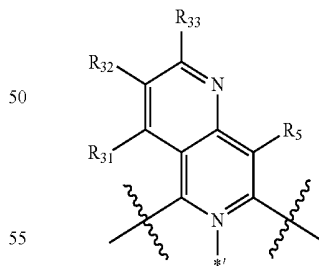
Formula 4-53



Formula 5-1

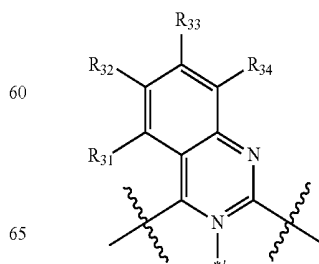


Formula 5-2



Formula 5-3

Formula 5-4



Formula 5-5

Formula 5-6

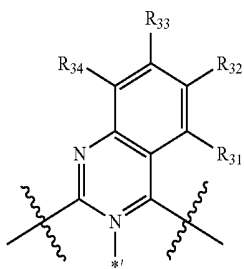
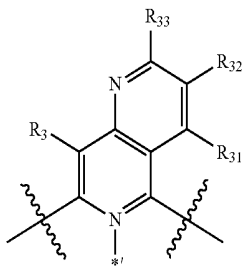
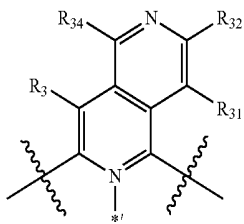
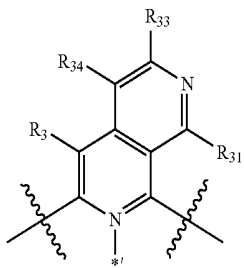
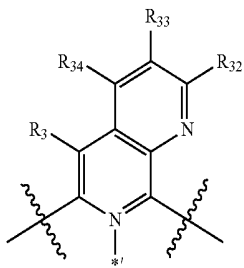
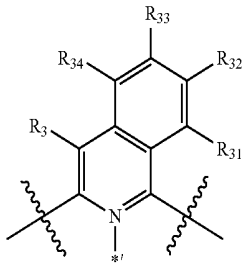
Formula 5-7

Formula 5-8

Formula 5-9

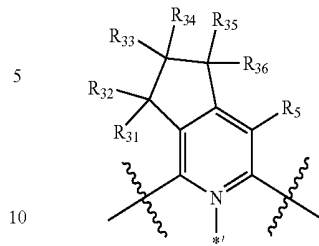
Formula 5-10

167
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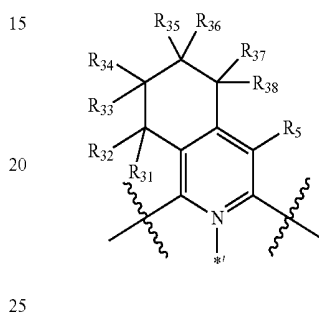


168
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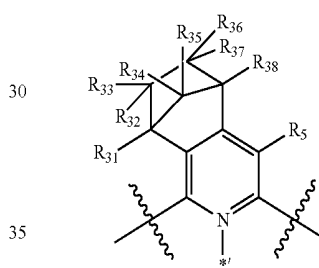
Formula 5-11



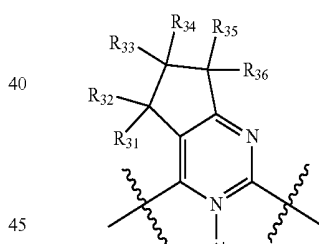
Formula 5-12 15



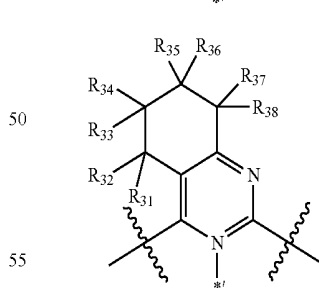
Formula 5-13



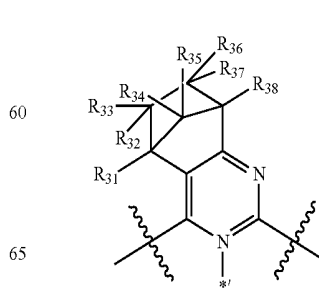
Formula 5-14



Formula 5-15



Formula 5-16



Formula 5-17

Formula 5-18

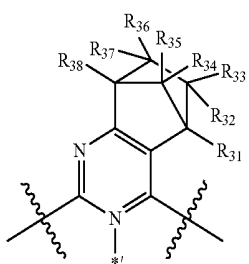
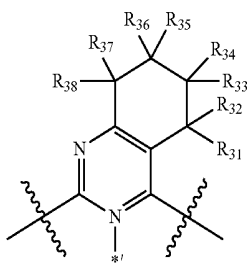
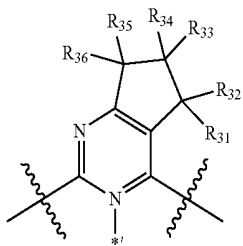
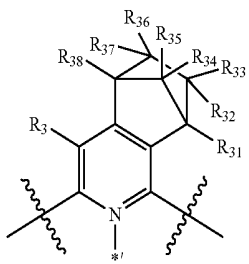
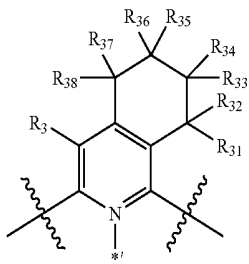
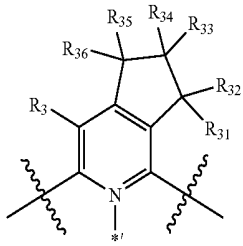
Formula 5-19

Formula 5-20

Formula 5-21

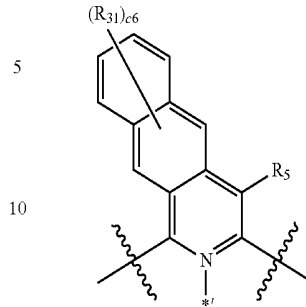
Formula 5-22

169
-continued

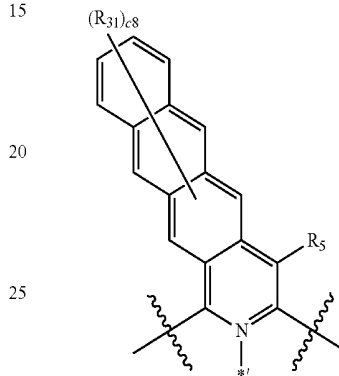


170
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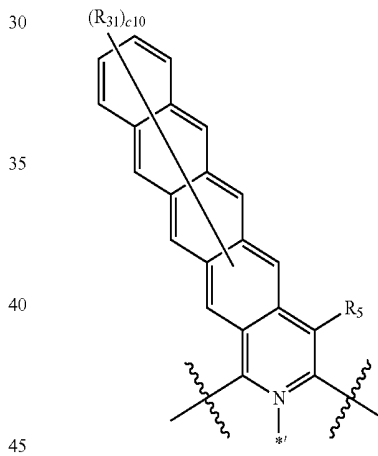
Formula 5-23



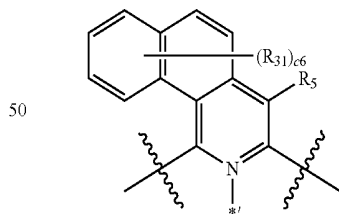
Formula 5-24



Formula 5-25

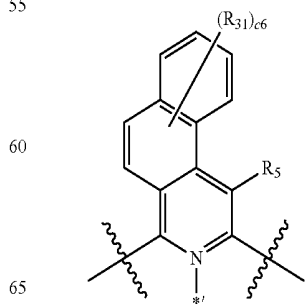


Formula 5-26



Formula 5-27

Formula 5-28



Formula 5-29

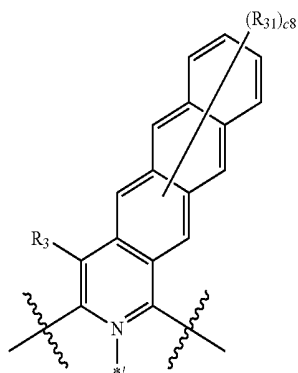
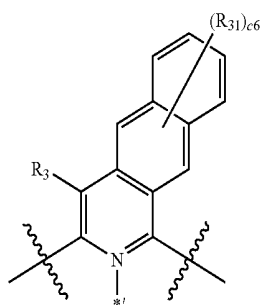
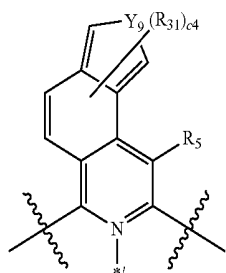
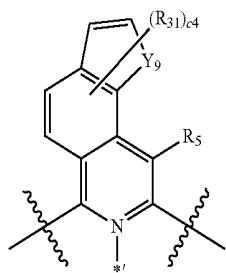
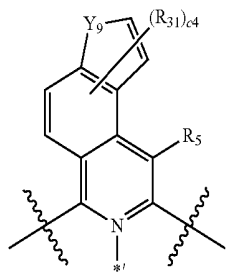
Formula 5-30

Formula 5-31

Formula 5-32

Formula 5-33

171
-continued



172
-continued

Formula 5-34

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Formula 5-35

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Formula 5-36

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Formula 5-37

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Formula 5-38

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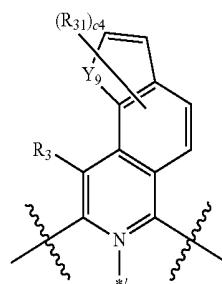
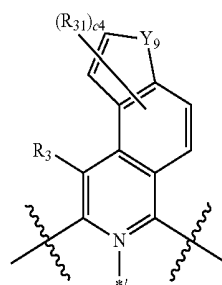
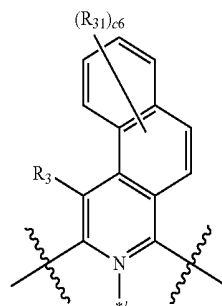
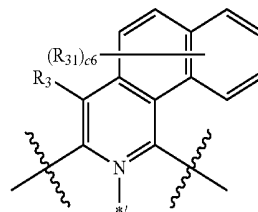
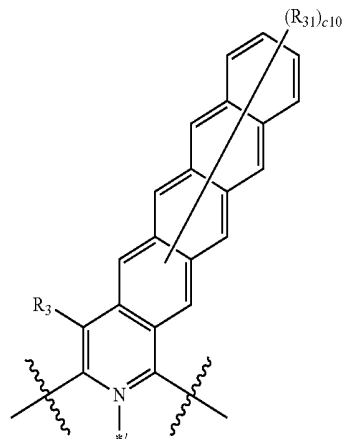
Formula 5-39

Formula 5-40

Formula 5-41

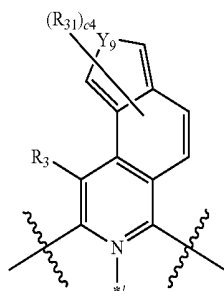
Formula 5-42

Formula 5-43



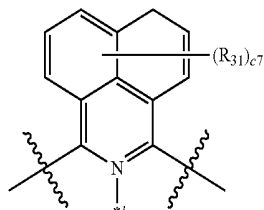
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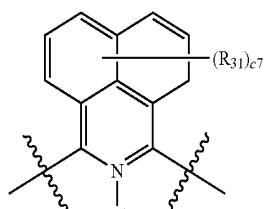
Formula 5-44

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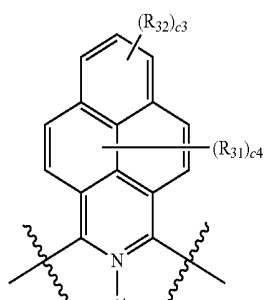
Formula 5-45

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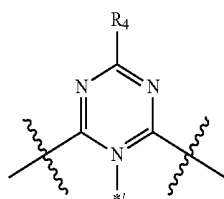
Formula 5-46

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Formula 5-47

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Formula 5-48

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wherein, in the above Formulae,

Y_7 and Y_8 are each independently O or S,

Y_9 is O, S, or $N(R_{39})$,

R_3 to R_7 and R_{11} to R_{39} are each independently selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, $-SF_5$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid 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

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

c_3 is an integer selected from 0 to 3,

c_4 is an integer selected from 0 to 4,

c_6 is an integer selected from 0 to 6,

c_7 is an integer selected from 0 to 7,

c_8 is an integer selected from 0 to 8,

c_{10} is an integer selected from 0 to 10,

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

deuterium, $-F$, $-Cl$, $-Br$, $-I$, $-CD_3$, $-CD_2H$, $-CDH_2$, $-CF_3$, $-CF_2H$, $-CFH_2$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid 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;

a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60} alkynyl group, and a C_1 - C_{60} alkoxy group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, $-CD_3$, $-CD_2H$, $-CDH_2$, $-CF_3$, $-CF_2H$, $-CFH_2$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $-N(Q_{11})(Q_{12})$, $-Si(Q_{13})(Q_{14})(Q_{15})$, $-B(Q_{16})(Q_{17})$, and $-P(=O)(Q_{18})(Q_{19})$;

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

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

densed heteropolycyclic group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, 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), —B(Q₂₆)(Q₂₇), and —P(=O)(Q₂₈)(Q₂₉); and —N(Q₃₁)(Q₃₂), —Si(Q₃₃)(Q₃₄)(Q₃₅), —B(Q₃₆)(Q₃₇), and —P(=O)(Q₃₈)(Q₃₉),

wherein Q₁ to Q₉, Q₁₁ to Q₁₉, Q₂₁ to Q₂₉, and Q₃₁ to Q₃₉ are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid 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 aryl group substituted with at least one selected from a C₁-C₆₀ alkyl group and a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

2. The organometallic compound of claim 1, wherein R₃ to R₇ and R₁₁ to R₃₉ are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid 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-C₂₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, 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, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group;

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

group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazoliny group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group;

a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazoliny group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, 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 cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl

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

$-\text{N}(\text{Q}_1)(\text{Q}_2)$, $-\text{Si}(\text{Q}_3)(\text{Q}_4)(\text{Q}_5)$, $-\text{B}(\text{Q}_6)(\text{Q}_7)$, and $-\text{P}(=\text{O})(\text{Q}_8)(\text{Q}_9)$,

wherein Q_1 to Q_9 are each independently selected from $-\text{CH}_3$, $-\text{CD}_3$, $-\text{CD}_2\text{H}$, $-\text{CDH}_2$, $-\text{CH}_2\text{CH}_3$, $-\text{CH}_2\text{CD}_3$, $-\text{CH}_2\text{CD}_2\text{H}$, $-\text{CH}_2\text{CDH}_2$, $-\text{CHDCH}_3$, $-\text{CHDCD}_2\text{H}$, $-\text{CHDCDH}_2$, $-\text{CHDCD}_3$, $-\text{CD}_2\text{CD}_3$, $-\text{CD}_2\text{CD}_2\text{H}$, and $-\text{CD}_2\text{CDH}_2$;

an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

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

3. The organometallic compound of claim 1, wherein R_3 to R_7 and R_{11} to R_{39} are each independently selected from hydrogen, deuterium, $-\text{F}$, a cyano group, a nitro group, $-\text{SF}_5$, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an iso-hexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an iso-heptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an iso-octyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an iso-nonyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an iso-decyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an iso-hexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an iso-heptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an iso-octyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an iso-nonyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an iso-decyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl

group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, $-\text{F}$, $-\text{CD}_3$, $-\text{CD}_2\text{H}$, $-\text{CDH}_2$, $-\text{CF}_3$, $-\text{CF}_2\text{H}$, $-\text{CFH}_2$, a cyano group, a nitro group, a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

$-\text{N}(\text{Q}_1)(\text{Q}_2)$, $-\text{Si}(\text{Q}_3)(\text{Q}_4)(\text{Q}_5)$, $-\text{B}(\text{Q}_6)(\text{Q}_7)$, and $-\text{P}(=\text{O})(\text{Q}_8)(\text{Q}_9)$,

wherein Q_1 to Q_9 are each independently selected from $-\text{CH}_3$, $-\text{CD}_3$, $-\text{CD}_2\text{H}$, $-\text{CDH}_2$, $-\text{CH}_2\text{CH}_3$, $-\text{CH}_2\text{CD}_3$, $-\text{CH}_2\text{CD}_2\text{H}$, $-\text{CH}_2\text{CDH}_2$, $-\text{CHDCH}_3$, $-\text{CHDCD}_2\text{H}$, $-\text{CHDCDH}_2$, $-\text{CHDCD}_3$, $-\text{CD}_2\text{CD}_3$, $-\text{CD}_2\text{CD}_2\text{H}$, and $-\text{CD}_2\text{CDH}_2$;

an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

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

4. The organometallic compound of claim 1, wherein R_3 to R_7 and R_{11} to R_{39} are each independently selected from hydrogen, deuterium, $-\text{F}$, a cyano group, a nitro group, $-\text{SF}_5$, $-\text{CH}_3$, $-\text{CD}_3$, $-\text{CD}_2\text{H}$, $-\text{CDH}_2$, $-\text{CF}_3$, $-\text{CF}_2\text{H}$, $-\text{CFH}_2$, groups represented by Formulae 9-1 to 9-19, groups represented by Formulae 10-1 to 10-38, and $-\text{Si}(\text{Q}_3)(\text{Q}_4)(\text{Q}_5)$:

 Formula 9-1

 Formula 9-2


 Formula 9-3

 Formula 9-4

 Formula 9-5

 Formula 9-6

 Formula 9-7

 Formula 9-8

 Formula 9-9

 Formula 9-10


 Formula 9-11

 Formula 9-12

 Formula 9-13

 Formula 9-14

 Formula 9-15

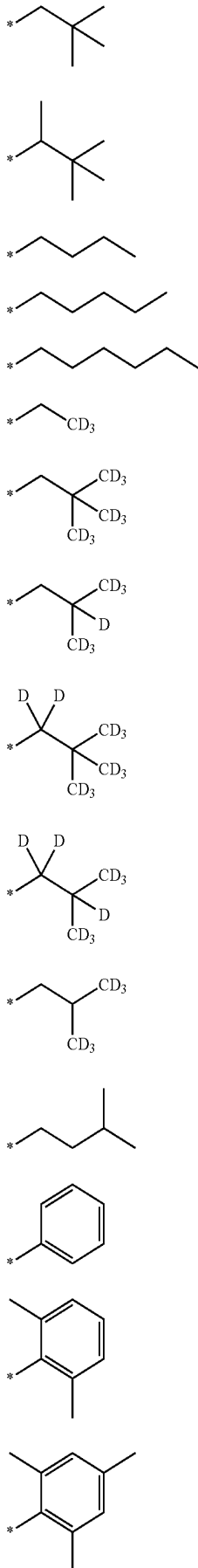
 Formula 9-16

 Formula 9-17

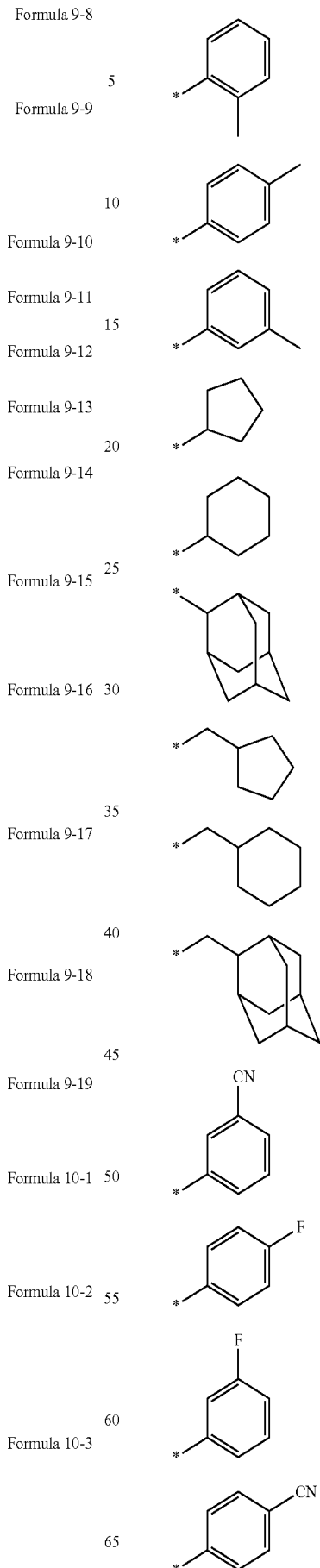
 Formula 9-18

 Formula 9-19

179
-continued



180
-continued



Formula 10-4

Formula 10-5

Formula 10-6

Formula 10-7

Formula 10-8

Formula 10-9

Formula 10-10

Formula 10-11

Formula 10-12

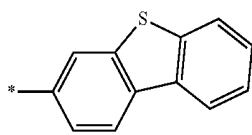
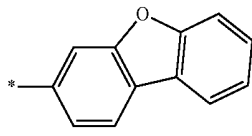
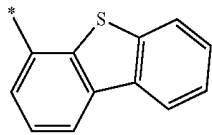
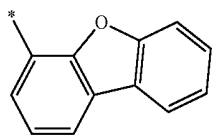
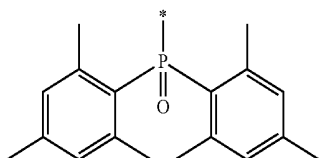
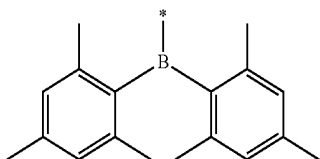
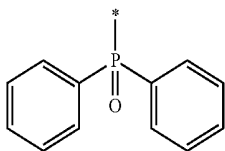
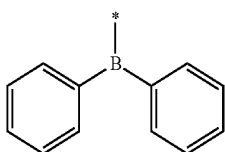
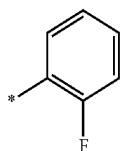
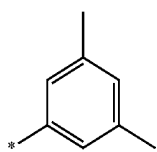
Formula 10-13

Formula 10-14

Formula 10-15

Formula 10-16

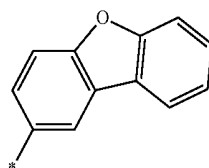
181
-continued



182
-continued

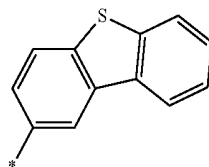
Formula 10-17

5



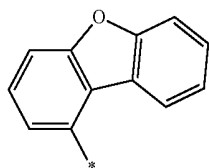
Formula 10-18

10



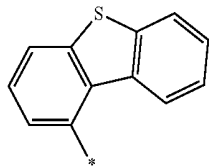
Formula 10-19

15



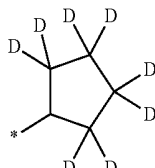
Formula 10-20

20



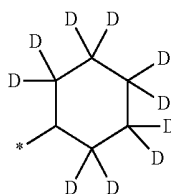
Formula 10-21

30



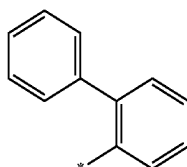
Formula 10-22

35



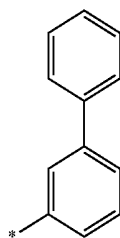
Formula 10-23

40



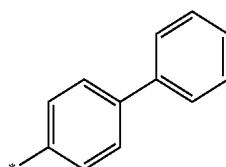
Formula 10-24

50



Formula 10-25

55



Formula 10-26

65

Formula 10-27

Formula 10-28

Formula 10-29

Formula 10-30

Formula 10-31

Formula 10-32

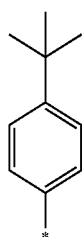
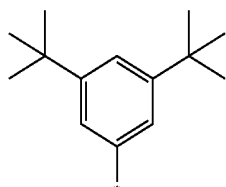
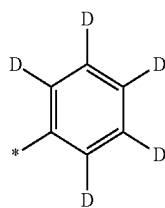
Formula 10-33

Formula 10-34

Formula 10-35

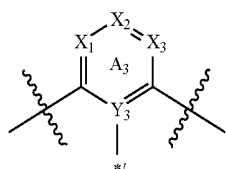
183

-continued



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

5. The organometallic compound of claim 1, wherein the moiety represented by



in Formula 2 is represented by one of Formulae 5-1 to 5-28, 5-29, and 5-45.

6. The organometallic compound of claim 1, wherein T_1 is a single bond,

T_2 is a group selected from $*-O-*$, $*-S-*$, $*-C(R_6)(R_7)-*$, $*-N(R_6)-*$, and $*-Si(R_6)(R_7)-*$, wherein * and *' in each of the foregoing groups independently indicate a binding site to a neighboring atom, and

R_6 and R_7 are optionally bound to each other via a first linking group,

wherein the first linking group is selected from a single bond, a C_1-C_3 alkylene group, and a C_2-C_3 alkenylene group;

a C_1-C_3 alkylene group and a C_2-C_3 alkenylene group, each substituted with at least one selected from deuterium, a cyano group, C_1-C_{10} alkyl group, C_1-C_{10} alkoxy group, a phenyl group, and a biphenyl group, and

a_2 is 1.

7. An organometallic compound represented by Formula 1:



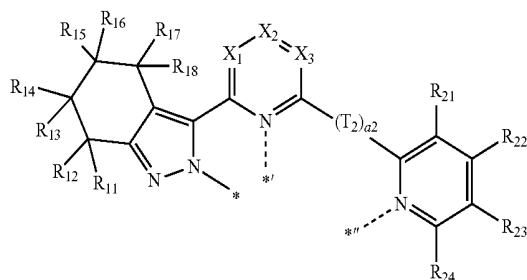
Formula 1

wherein L_1 in Formula 1 is selected from ligands represented by one of Formulae 2B to 2C:

184

Formula 10-36

5



Formula 2B

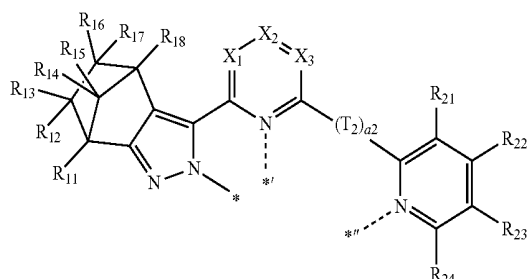
Formula 10-37 10

Formula 10-38

15

20

25



Formula 2C

M in Formula 1 is palladium, gold, or platinum,

L_2 in Formula 1 is selected from monodentate organic ligands,

wherein, in Formulae 2B to 2C,

T_2 is a group selected from $*-O-*$, $*-S-*$, $*-C(R_6)(R_7)-*$, $*-C(R_6)=*$, $*=C(R_6)-*$, $*-C(R_6)=C(R_7)-*$, $*-C(=O)-*$, $*-C(=S)-*$, $*-C\equiv C-*$, $*-N(R_6)-*$, $*-Si(R_6)(R_7)-*$, and $*-P(R_6)(R_7)-*$, wherein * and *' in each of the foregoing groups independently indicate a binding site to a neighboring atom,

R_6 and R_7 are optionally bound to each other to form a substituted or unsubstituted C_5-C_{30} carbocyclic group or a substituted or unsubstituted C_2-C_{30} heterocyclic group,

a_2 is an integer selected from 1 to 3,

X_1 is N or C(R_3), X_2 is N or C(R_4), X_3 is N or C(R_5), at least two selected from R_3 to R_5 are optionally bound to each other to form a substituted or unsubstituted C_5-C_{30} carbocyclic group or a substituted or unsubstituted C_2-C_{30} heterocyclic group,

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

R_3 to R_7 , R_{11} to R_{18} , and R_{21} to R_{24} are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, —SF₅, 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 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

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), —B(Q₆)(Q₇), and —P(=O)(Q₈)(Q₉), at least two of R₂₁ to R₂₄ are optionally bound to each other to form a substituted or unsubstituted C₅-C₃₀ carbocyclic group or a substituted or unsubstituted C₂-C₃₀ heterocyclic group,

at least one of substituents of the substituted C₁-C₆₀ alkyl group, substituted C₂-C₆₀ alkenyl group, substituted C₂-C₆₀ alkynyl group, substituted C₁-C₆₀ alkoxy group, substituted C₃-C₁₀ cycloalkyl group, substituted C₁-C₁₀ heterocycloalkyl group, substituted C₃-C₁₀ cycloalkenyl group, substituted C₁-C₁₀ heterocycloalkenyl group, substituted C₆-C₆₀ aryl group, substituted C₆-C₆₀ aryloxy group, substituted C₆-C₆₀ arylthio group, substituted C₁-C₆₀ heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic condensed heteropolycyclic group is selected from:

deuterium, —F, —Cl, —Br, —I, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, 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 deuterium, —F, —Cl, —Br, —I, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, 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), —B(Q₁₆)(Q₁₇), and —P(=O)(Q₁₈)(Q₁₉);

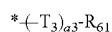
a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic 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 deuterium, —F, —Cl, —Br, —I, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, 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), —B(Q₂₆)(Q₂₇), and —P(=O)(Q₂₈)(Q₂₉); and —N(Q₃₁)(Q₃₂), —Si(Q₃₃)(Q₃₄)(Q₃₅), —B(Q₃₆)(Q₃₇), and —P(=O)(Q₃₈)(Q₃₉),

wherein Q₁ to Q₉, Q₁₁ to Q₁₉, Q₂₁ to Q₂₉, and Q₃₁ to Q₃₉ are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid 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 aryl group substituted with at least one selected from a C₁-C₆₀ alkyl group and 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.

8. The organometallic compound of claim 1, wherein L₂ in Formula 1 is selected from ligands represented by Formula 6-1:



Formula 6-1

wherein, in Formula 6-1,

T₃ is a group selected from a single bond, *—O—*, *—S—*, *—C(R₆₂)(R₆₃)—*, *—C(R₆₂)=*, *—C(R₆₂)—*, *—C(R₆₂)=C(R₆₃)—*, *—C(=O)—*, *—C(=S)—*, *—C≡C—*, and *—N(R₆₂)—*, wherein * and * in each of the foregoing groups independently indicate a binding site to a neighboring atom,

a₃ is an integer selected from 1 to 5,

R₆₁ is selected from hydrogen, deuterium, —F, —Cl, —Br, —I, —SF₅, 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 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

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condensed heteropolycyclic group, $-\text{N}(\text{Q}_1)(\text{Q}_2)$, $-\text{Si}(\text{Q}_3)(\text{Q}_4)(\text{Q}_5)$, $-\text{B}(\text{Q}_6)(\text{Q}_7)$, $-\text{P}(=\text{O})(\text{Q}_8)(\text{Q}_9)$, and $\text{P}(\text{Q}_{41})(\text{Q}_{42})(\text{Q}_{43})$,

wherein Q_1 to Q_9 and Q_{41} to Q_{43} are each independently selected from

$-\text{CH}_3$, $-\text{CD}_3$, $-\text{CD}_2\text{H}$, $-\text{CDH}_2$, $-\text{CH}_2\text{CH}_3$,
 $-\text{CH}_2\text{CD}_3$, $-\text{CH}_2\text{CD}_2\text{H}$, $-\text{CH}_2\text{CDH}_2$, $-\text{CHDC}_3$,
 $-\text{CHDCD}_2\text{H}$, $-\text{CHDCDH}_2$, $-\text{CHDCD}_3$,
 $-\text{CD}_2\text{CD}_3$, $-\text{CD}_2\text{CD}_2\text{H}$, and $-\text{CD}_2\text{CDH}_2$;

an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

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

R_{62} to R_{63} are each independently selected from

hydrogen, deuterium, $-\text{F}$, a cyano group, a nitro group, $-\text{SF}_5$, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an iso-hexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an iso-heptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an iso-octyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an iso-nonyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an iso-decyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a dibenzofuran group, and a dibenzothiophenyl group; and

a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an iso-hexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an iso-heptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an iso-octyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an iso-nonyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an iso-decyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a dibenzofuran group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, $-\text{F}$, $-\text{CD}_3$, $-\text{CD}_2\text{H}$, $-\text{CDH}_2$, $-\text{CF}_3$, $-\text{CF}_2\text{H}$, $-\text{CFH}_2$, a cyano group, a nitro group, a C_1 - C_{10} alkyl group, a C_1 - C_{10}

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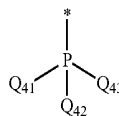
alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a dibenzofuran group, and a dibenzothiophenyl group,

R_{62} and R_{63} are optionally bound to each other to form a substituted or unsubstituted C_5 - C_{30} carbocyclic group or a substituted or unsubstituted C_2 - C_{30} heterocyclic group, and

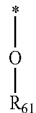
* in Formula 1 indicates a binding site to M.

9. The organometallic compound of claim 1, wherein L_2 in Formula 1 is selected from ligands represented by one of Formulae 13-1 to 13-49 and 14-1 to 14-28:

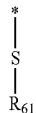
Formula 13-1



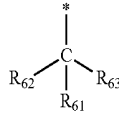
Formula 13-2



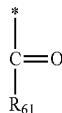
Formula 13-3



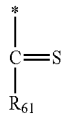
Formula 13-4



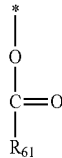
Formula 13-5



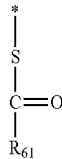
Formula 13-6



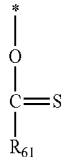
Formula 13-7



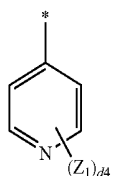
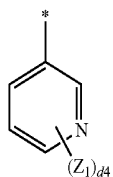
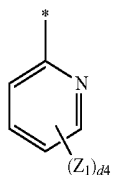
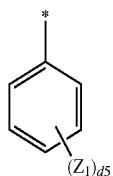
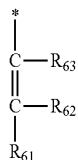
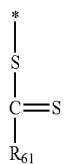
Formula 13-8



Formula 13-9

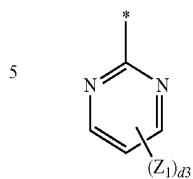


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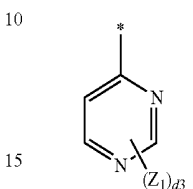


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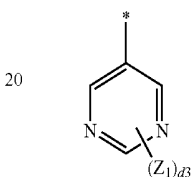
Formula 13-10



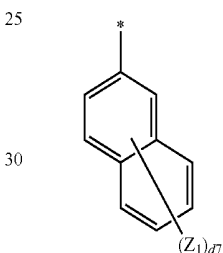
Formula 13-11



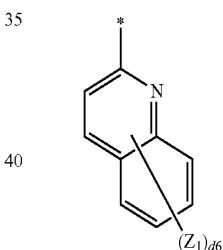
Formula 13-12



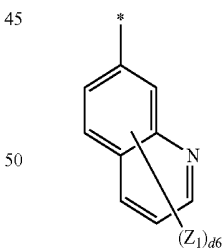
Formula 13-13



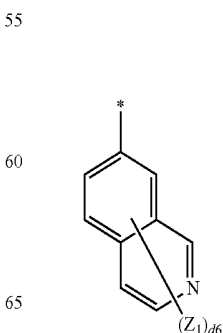
Formula 13-14



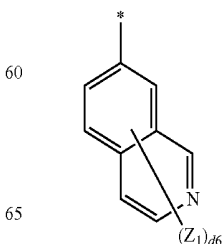
Formula 13-15



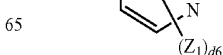
Formula 13-16



Formula 13-17



Formula 13-18



Formula 13-19

Formula 13-20

Formula 13-21

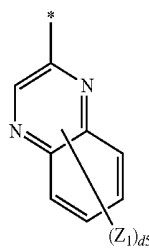
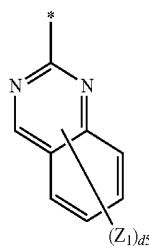
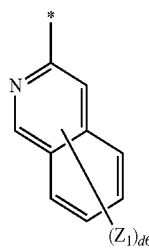
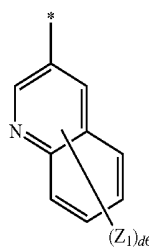
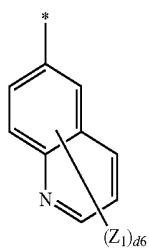
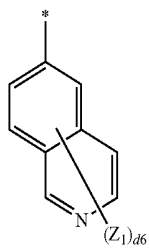
Formula 13-22

Formula 13-23

Formula 13-24

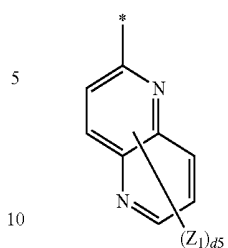
Formula 13-25

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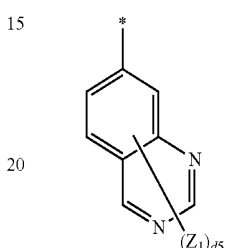


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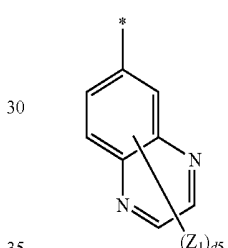
Formula 13-26



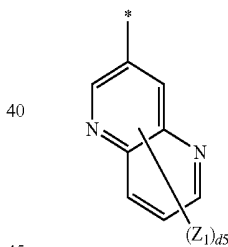
Formula 13-27



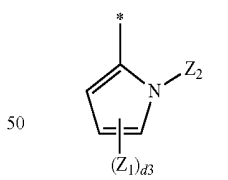
Formula 13-28



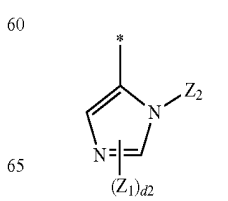
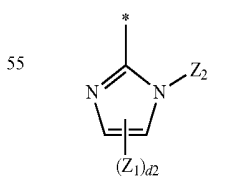
Formula 13-29



Formula 13-30



Formula 13-31



Formula 13-32

Formula 13-33

Formula 13-34

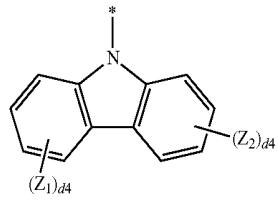
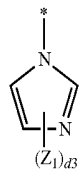
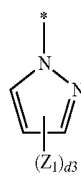
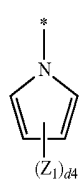
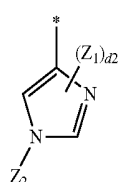
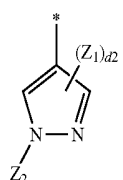
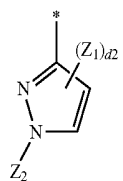
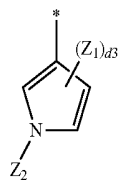
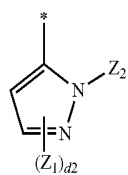
Formula 13-35

Formula 13-36

Formula 13-37

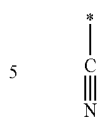
Formula 13-38

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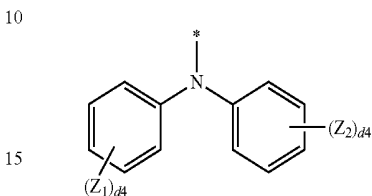


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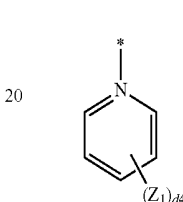
Formula 13-39



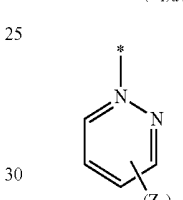
Formula 13-40



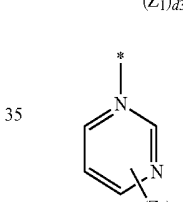
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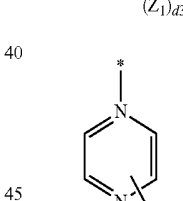
Formula 13-42



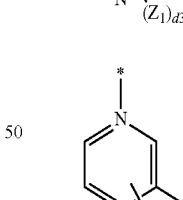
Formula 13-43



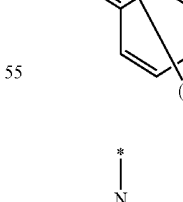
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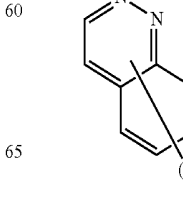
Formula 13-45



Formula 13-46



Formula 13-47



Formula 13-48

Formula 13-49

Formula 14-1

Formula 14-2

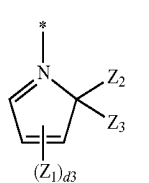
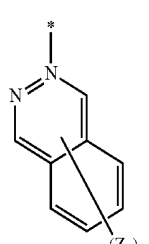
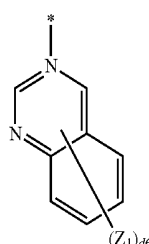
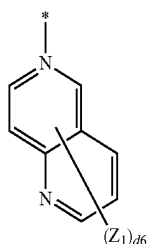
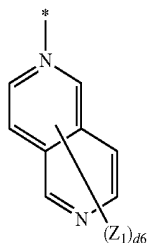
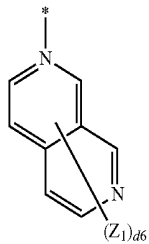
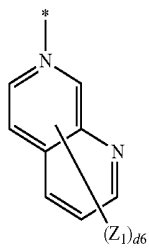
Formula 14-3

Formula 14-4

Formula 14-5

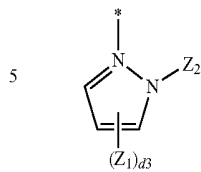
Formula 14-6

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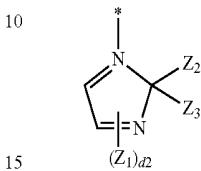


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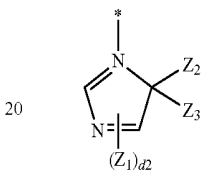
Formula 14-7



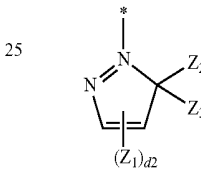
Formula 14-8



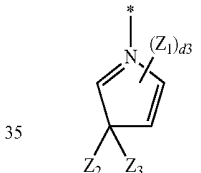
Formula 14-9



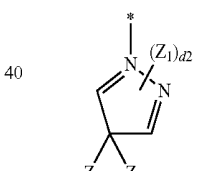
Formula 14-10



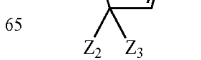
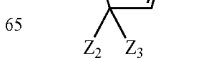
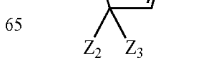
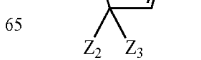
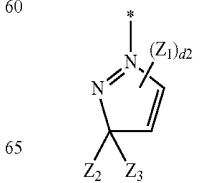
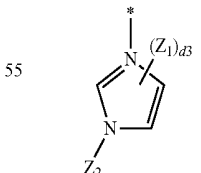
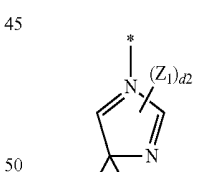
Formula 14-11



Formula 14-12



Formula 14-13



Formula 14-14

Formula 14-15

Formula 14-16

Formula 14-17

Formula 14-18

Formula 14-19

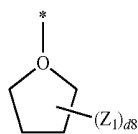
Formula 14-20

Formula 14-21

Formula 14-22

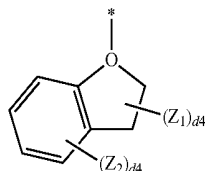
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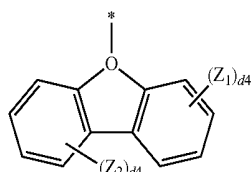
Formula 14-23

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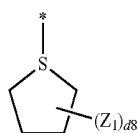
Formula 14-24

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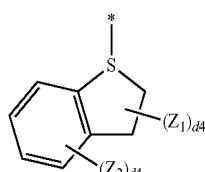
Formula 14-25

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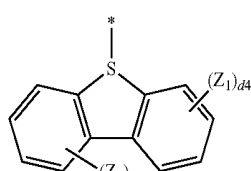
Formula 14-26

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Formula 14-27

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Formula 14-28

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wherein, in Formulae 13-1 to 13-49 and 14-1 to 14-28, R_{61} is selected from

hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid 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-C₂₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, 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, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group;

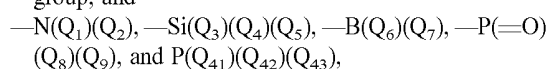
a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a

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

a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazoliny group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, 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 cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl

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



Z_1 to Z_3 are each independently selected from hydrogen, deuterium, $-\text{F}$, a cyano group, a nitro group, $-\text{SF}_5$, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an iso-hexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an iso-heptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an iso-octyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an iso-nonyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an iso-decyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an iso-hexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an iso-heptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an iso-octyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an iso-nonyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an iso-decyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, $-\text{F}$, $-\text{CD}_3$, $-\text{CD}_2\text{H}$, $-\text{CDH}_2$, $-\text{CF}_3$, $-\text{CF}_2\text{H}$, $-\text{CFH}_2$, a cyano group, a nitro group, a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a

pyridinyl group, a pyrimidinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

$$-\text{N}(\text{Q}_{31})(\text{Q}_{32}), -\text{Si}(\text{Q}_{33})(\text{Q}_{34})(\text{Q}_{35}), -\text{B}(\text{Q}_{36})(\text{Q}_{37}), \text{ and } -\text{P}(=\text{O})(\text{Q}_{38})(\text{Q}_{39}),$$

wherein Q_1 to Q_9 , Q_{31} to Q_{39} and Q_{41} to Q_{43} are each independently selected from $-\text{CH}_3$, $-\text{CD}_3$, $-\text{CD}_2\text{H}$, $-\text{CDH}_2$, $-\text{CH}_2\text{CH}_3$, $-\text{CH}_2\text{CD}_3$, $-\text{CH}_2\text{CD}_2\text{H}$, $-\text{CH}_2\text{CDH}_2$, $-\text{CHDCH}_3$, $-\text{CHDCD}_2\text{H}$, $-\text{CHD}-\text{CDH}_2$, $-\text{CHDCD}_3$, $-\text{CD}_2\text{CD}_3$, $-\text{CD}_2\text{CD}_2\text{H}$, and $-\text{CD}_2\text{CDH}_2$;

an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

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

d2 is an integer selected from 1 and 2,

d3 is an integer selected from 1 to 3,

d4 is an integer selected from 1 to 4,

d5 is an integer selected from 1 to 5,

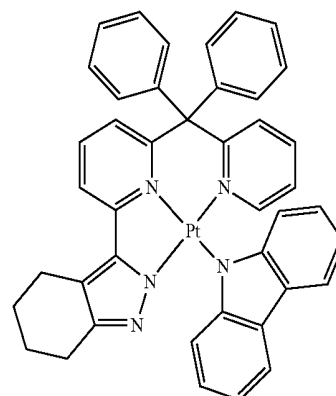
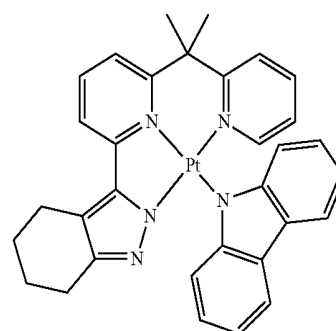
d6 is an integer selected from 1 to 6,

d7 is an integer selected from 1 to 7,

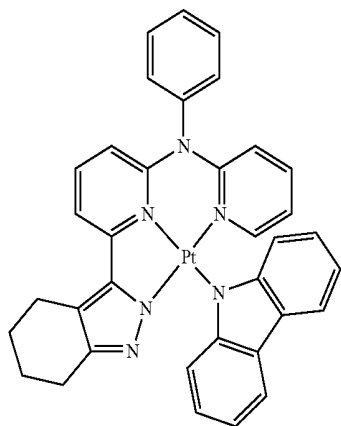
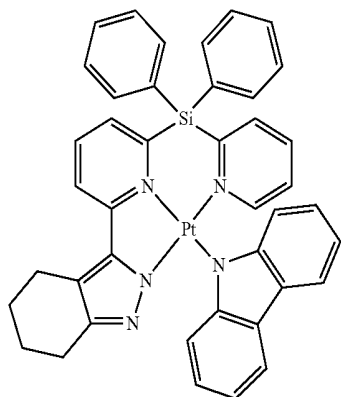
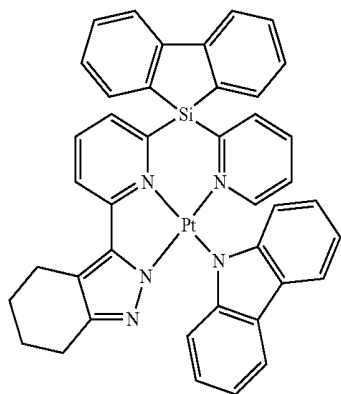
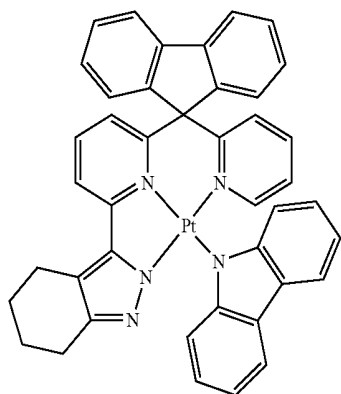
d8 is an integer selected from 1 to 8, and

* in Formula 1 indicates a binding site to M.

10. An organometallic compound being one of Compounds 1 to 180:

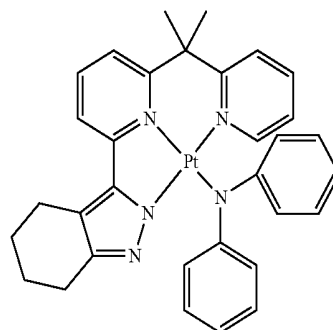


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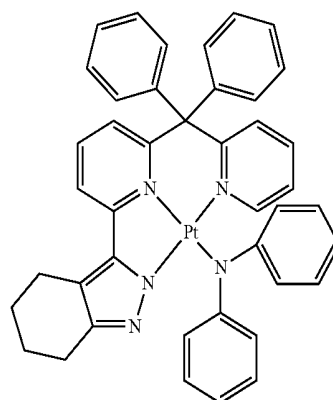


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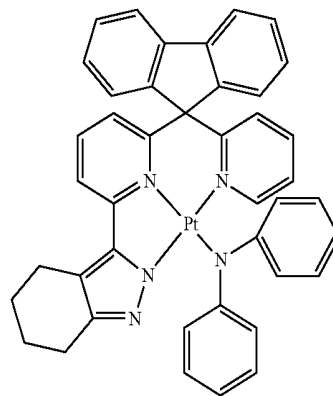
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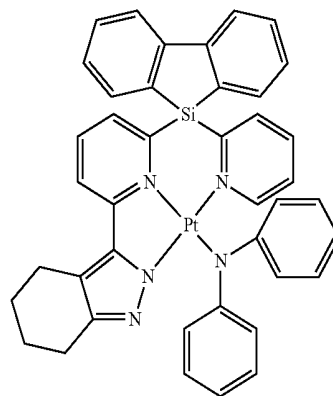
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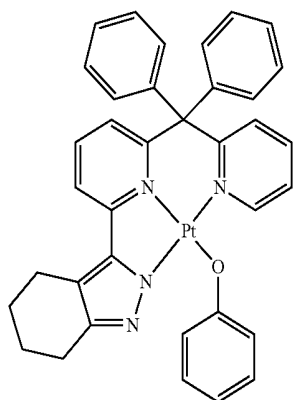
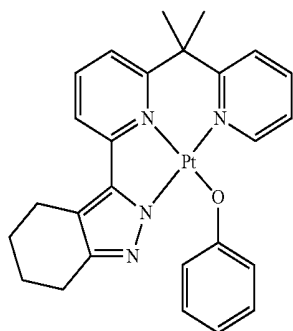
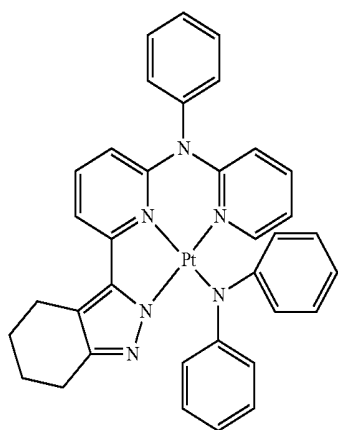
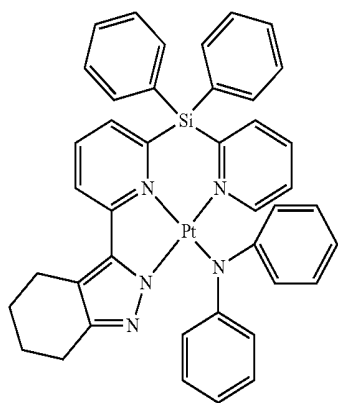
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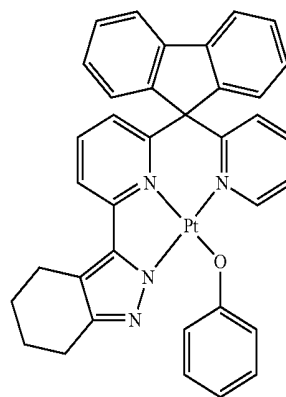
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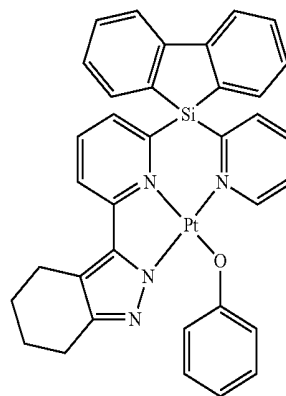
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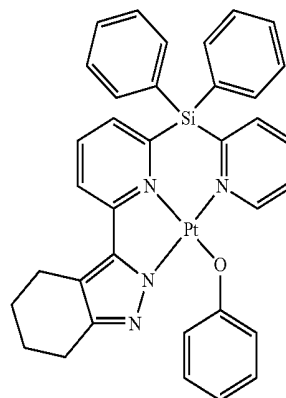


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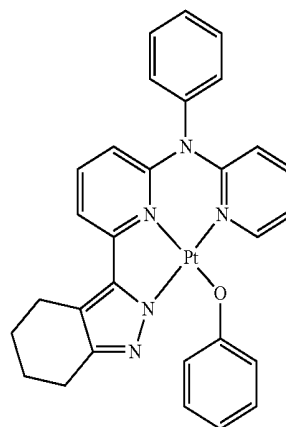


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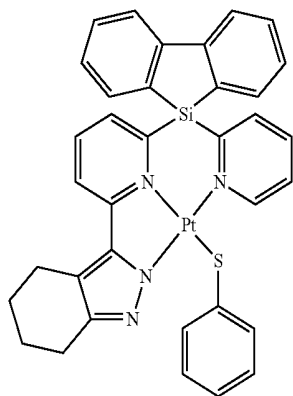
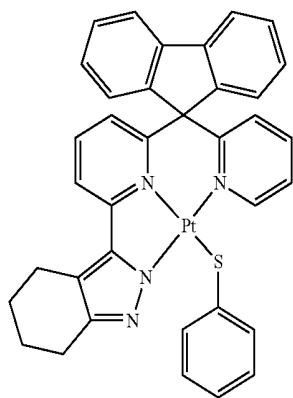
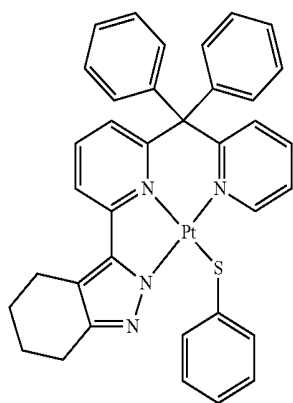
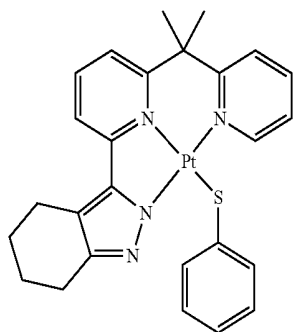
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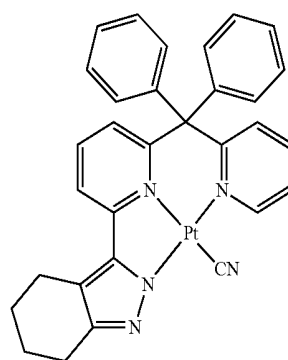
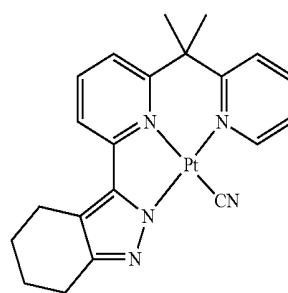
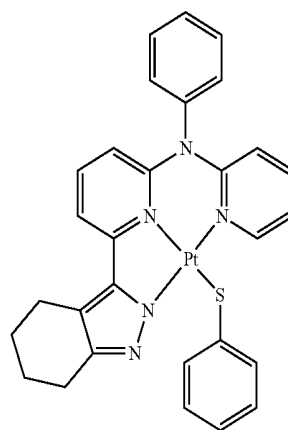
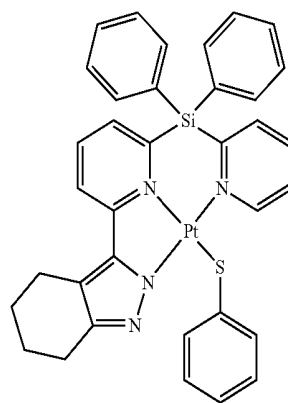
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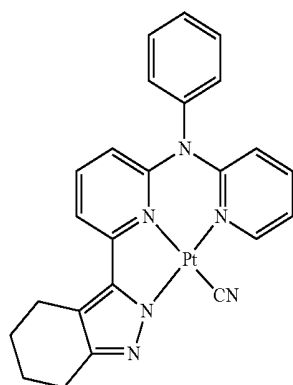
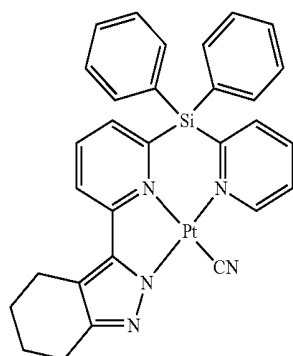
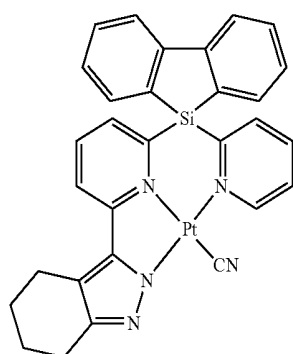
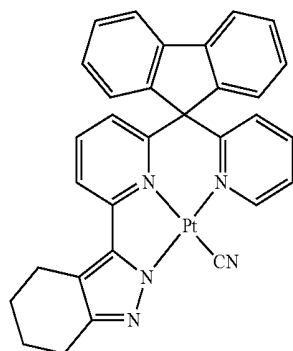
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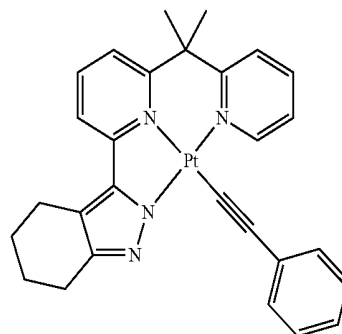
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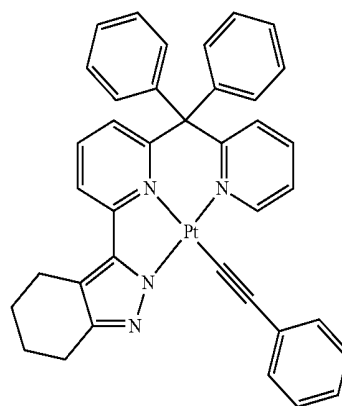
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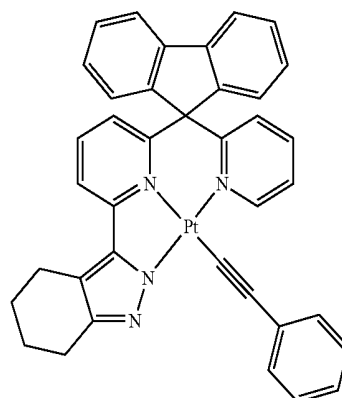
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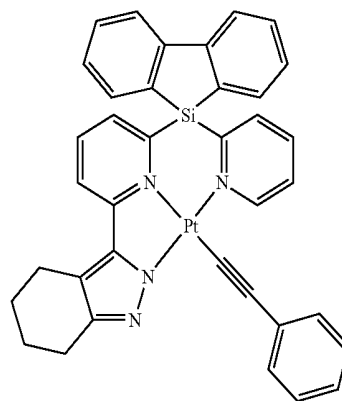
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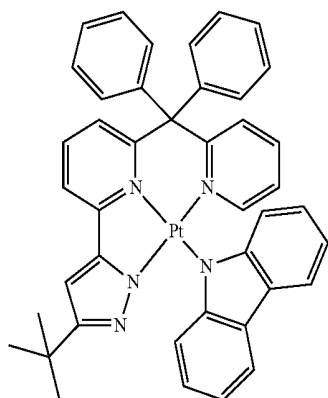
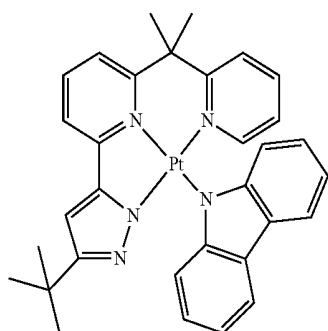
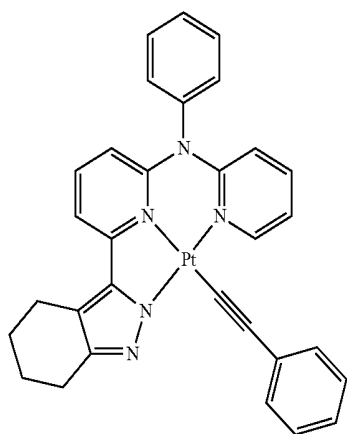
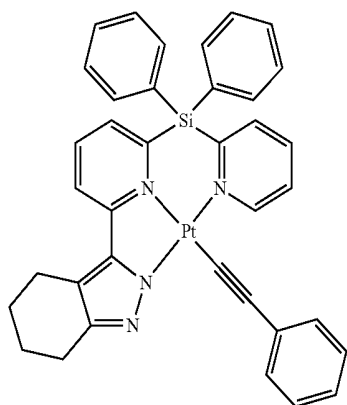
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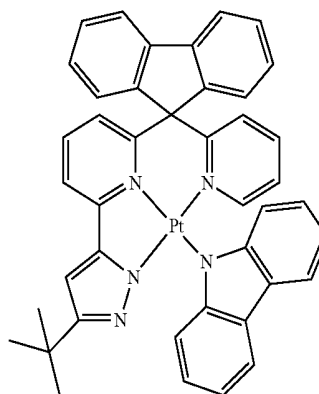
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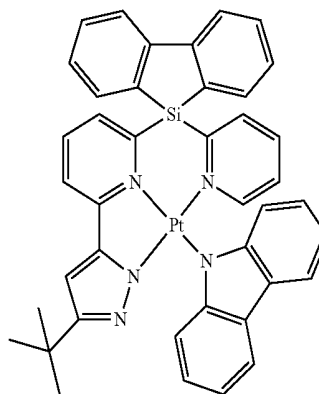
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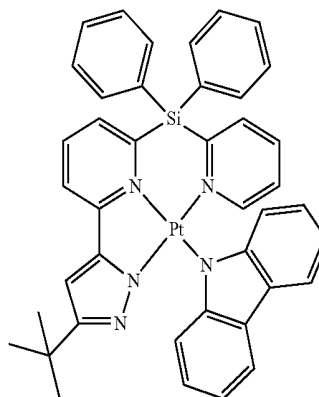


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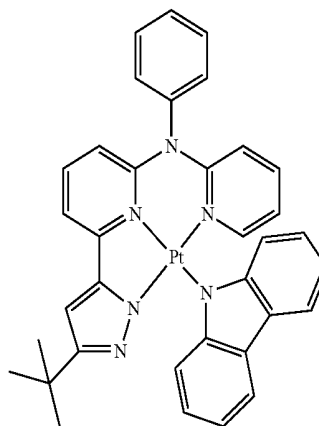


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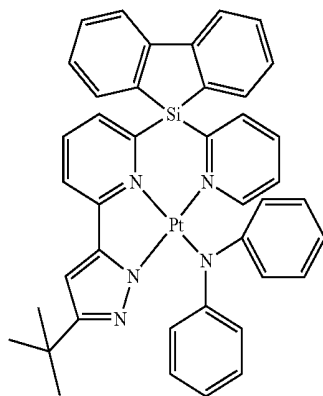
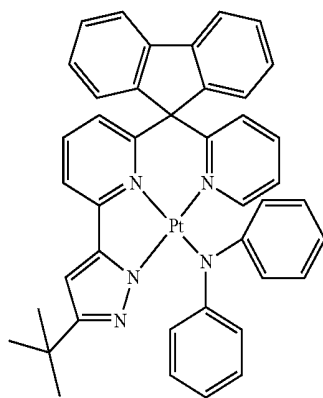
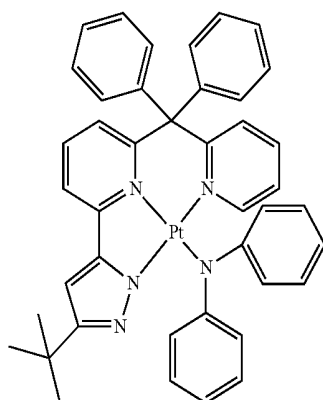
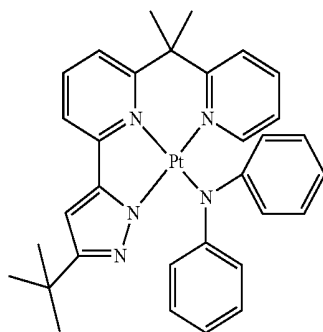
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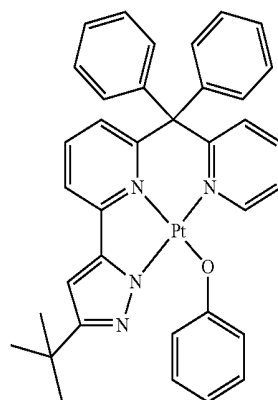
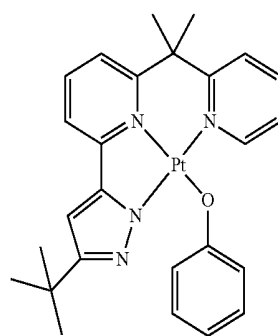
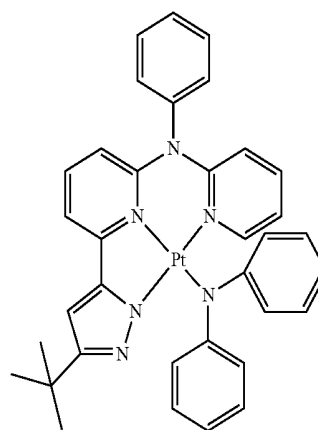
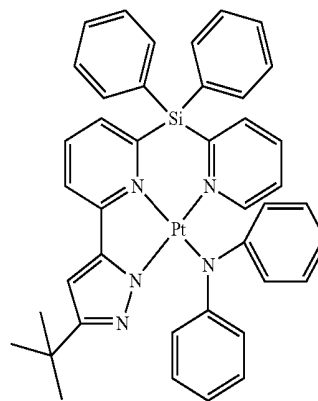
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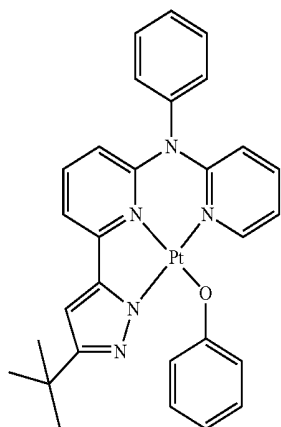
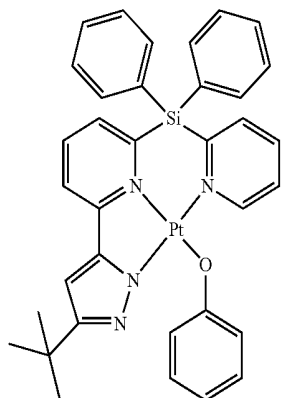
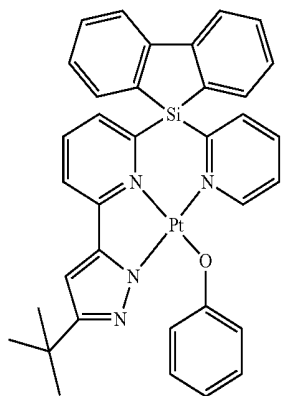
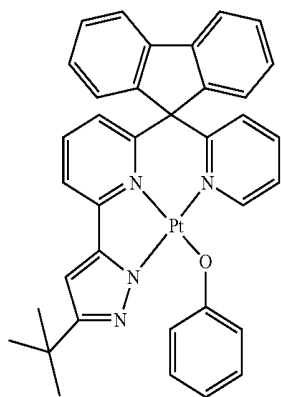
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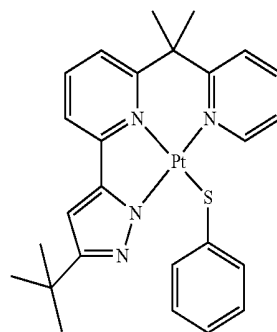
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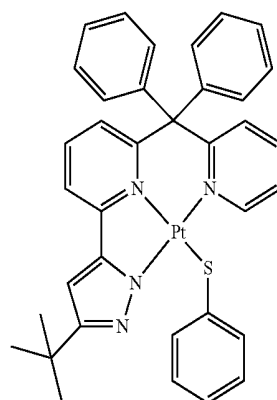


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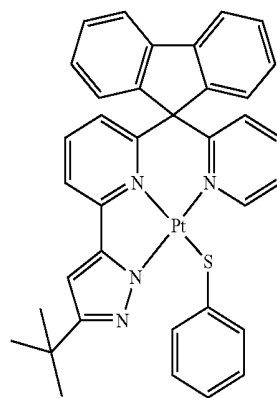
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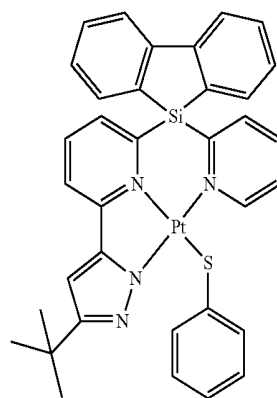
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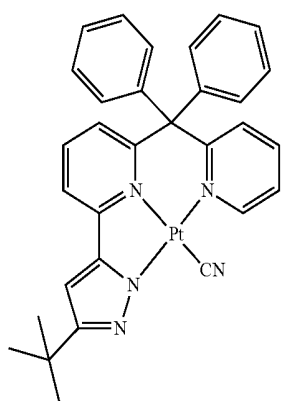
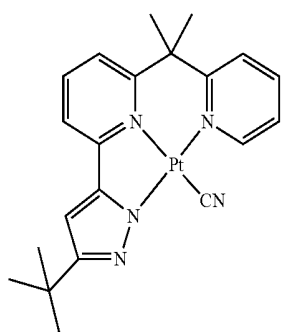
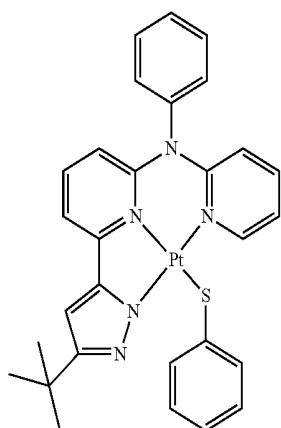
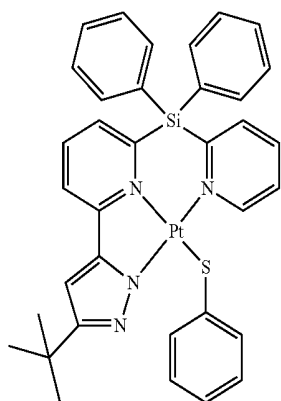
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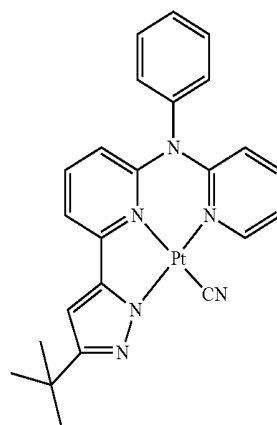
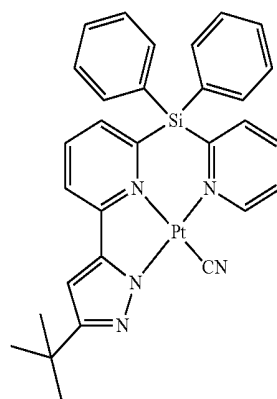
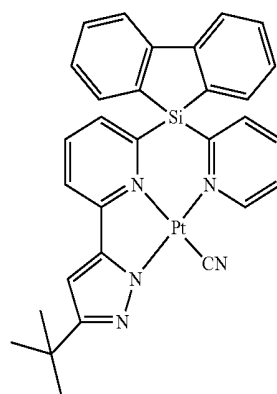
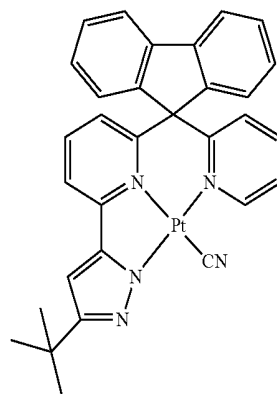
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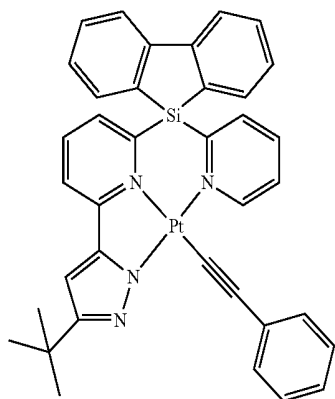
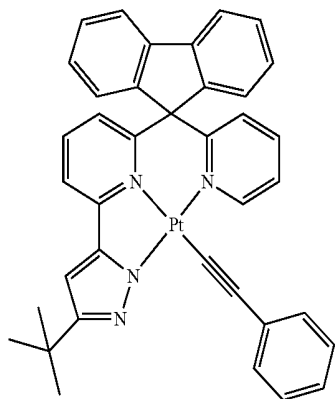
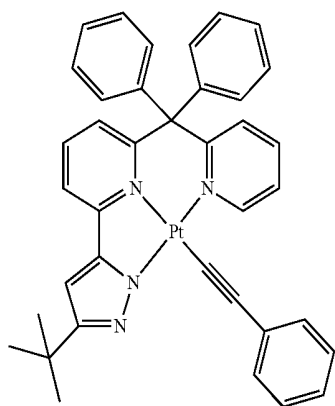
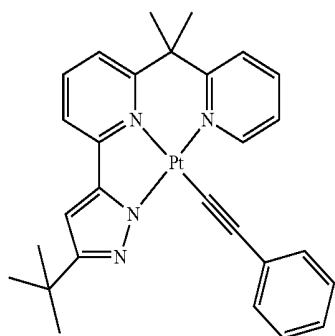
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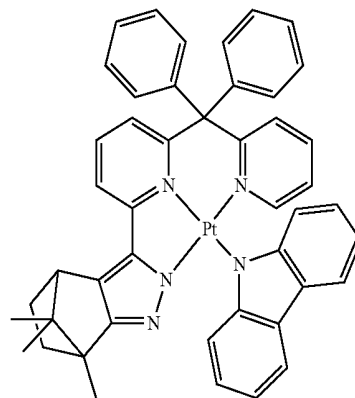
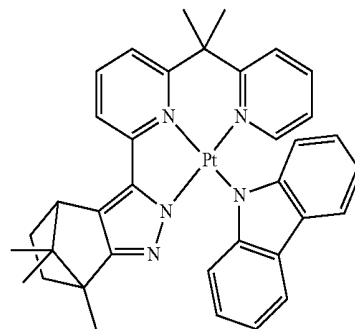
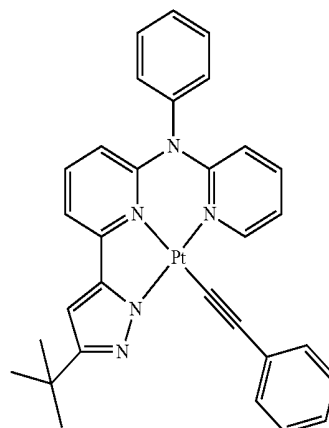
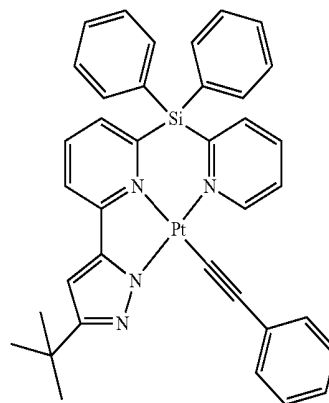
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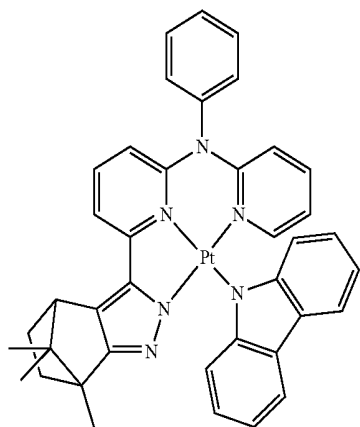
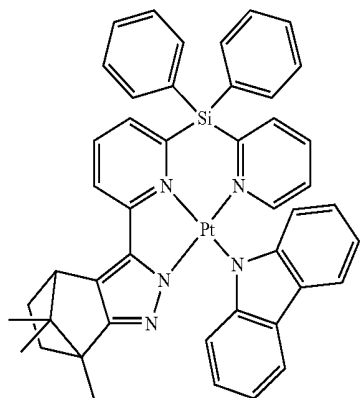
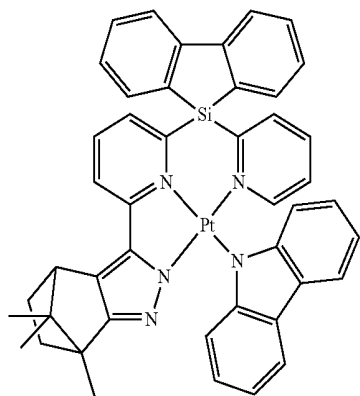
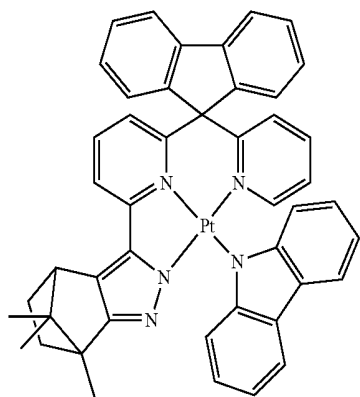
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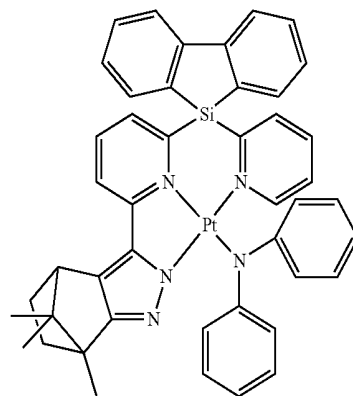
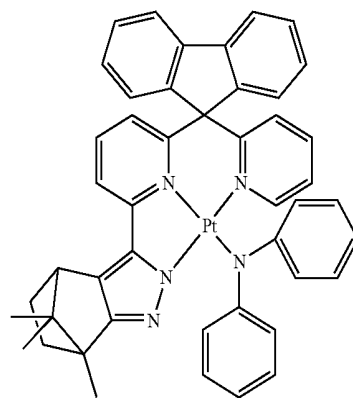
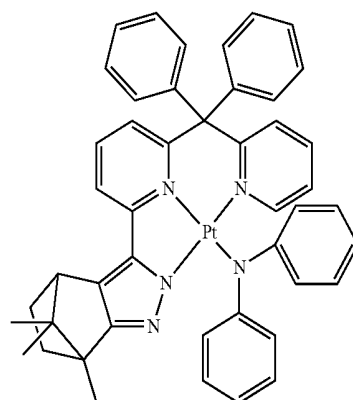
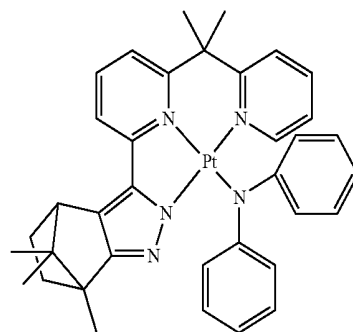
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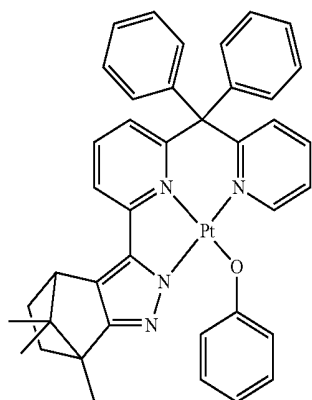
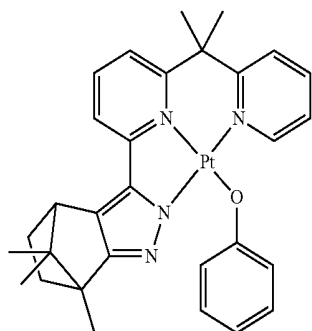
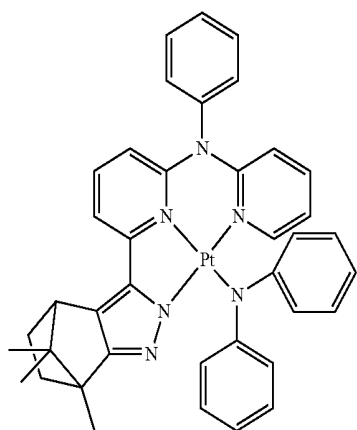
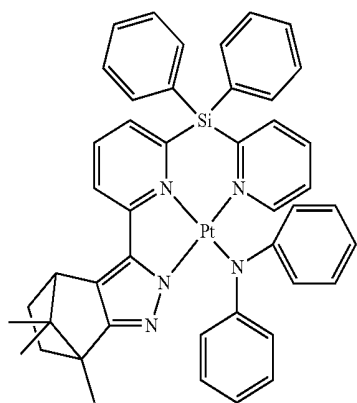
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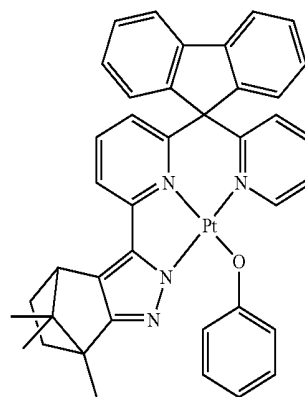
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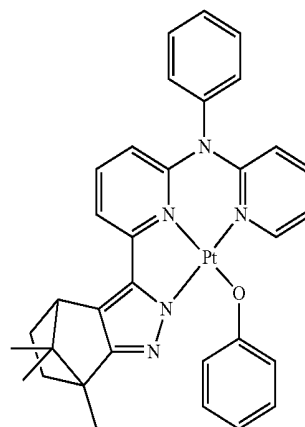
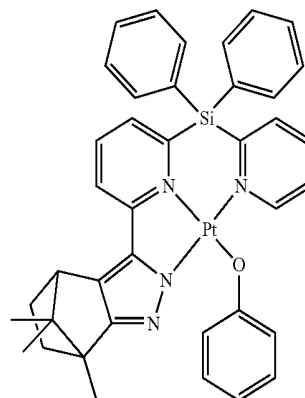
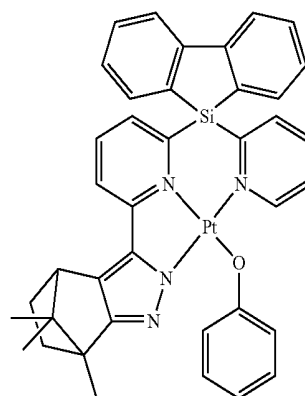
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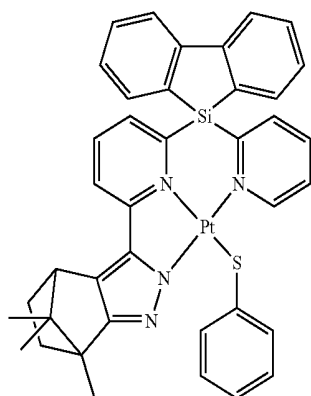
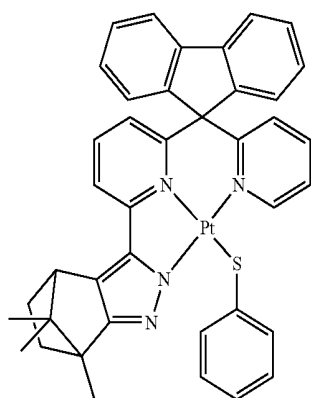
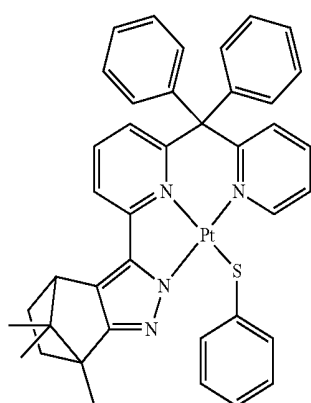
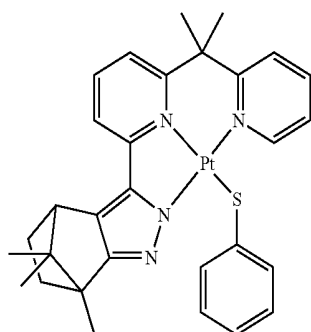
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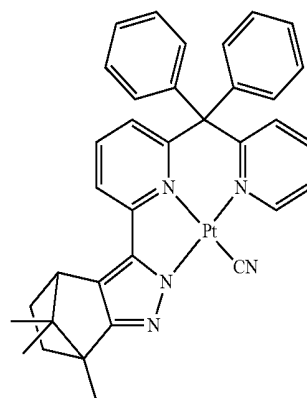
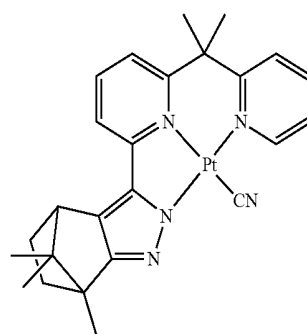
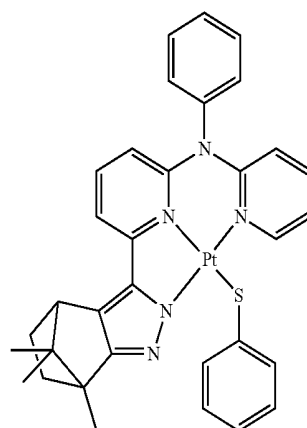
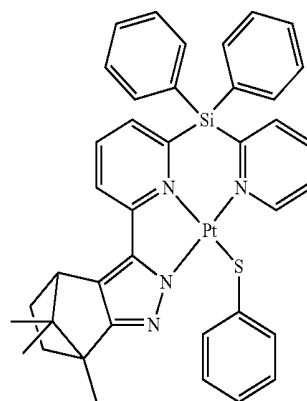
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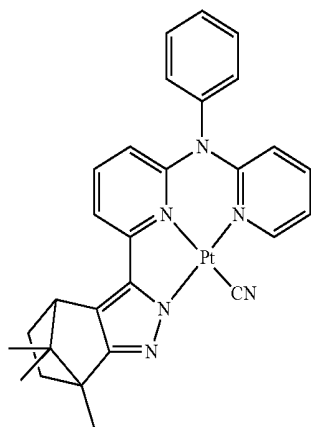
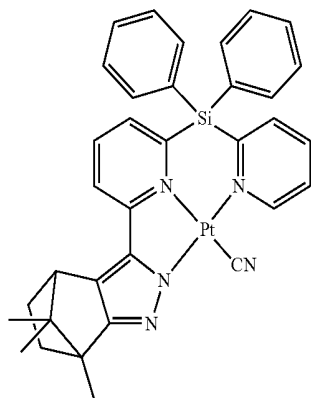
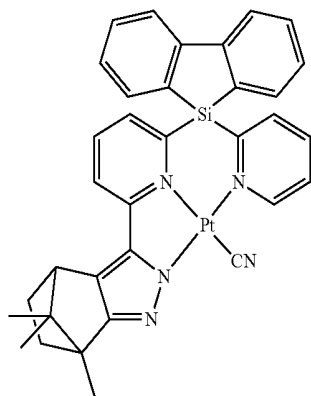
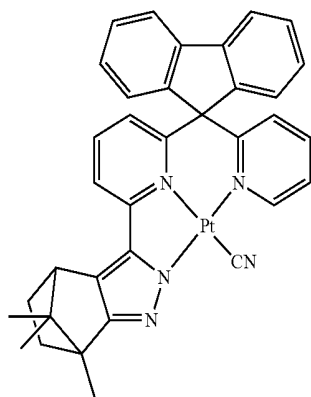
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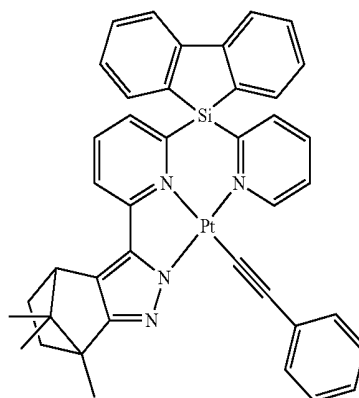
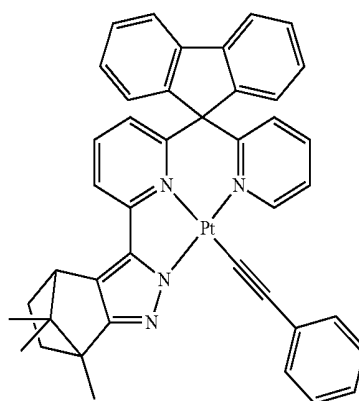
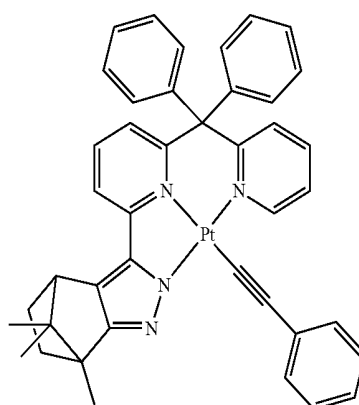
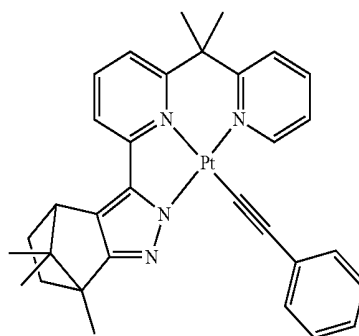
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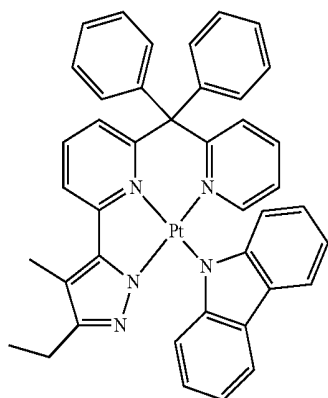
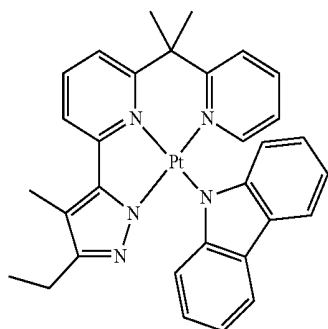
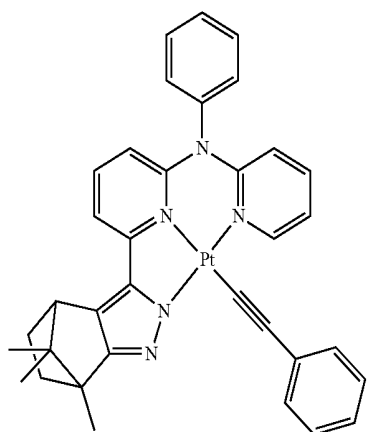
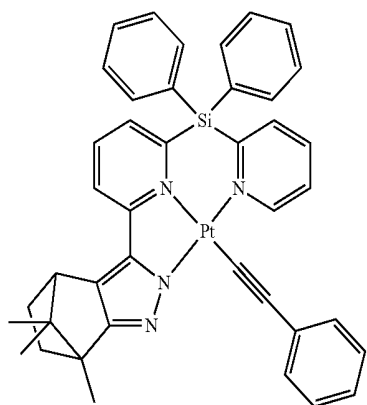
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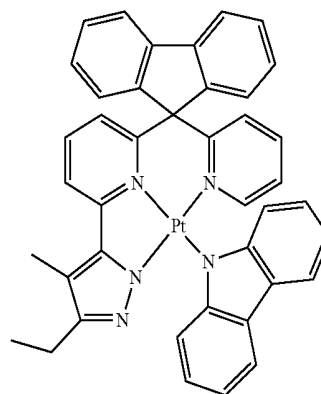
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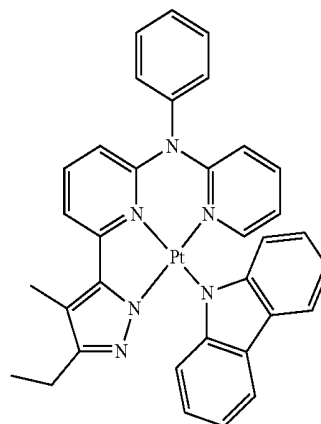
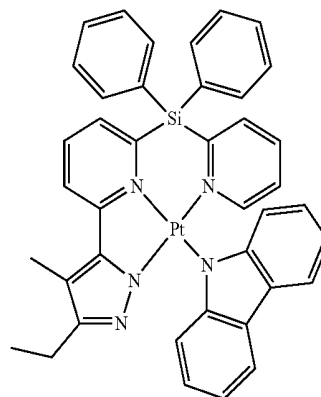
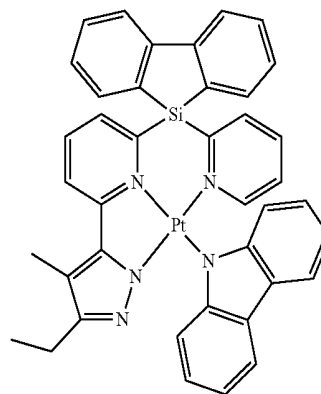
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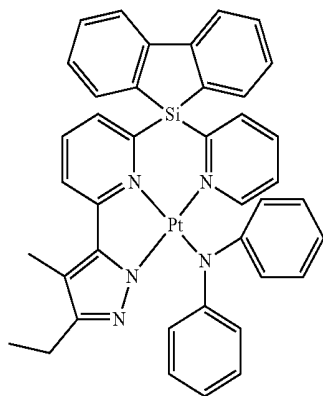
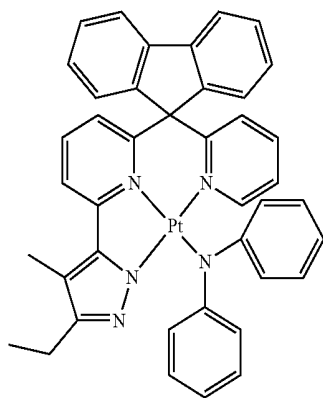
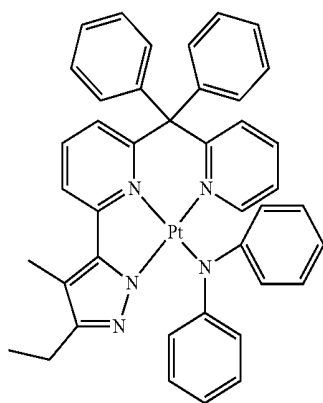
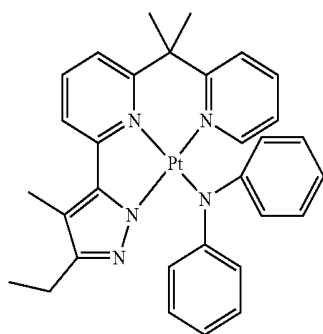
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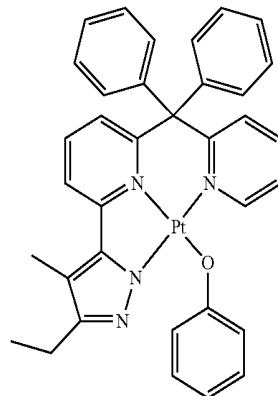
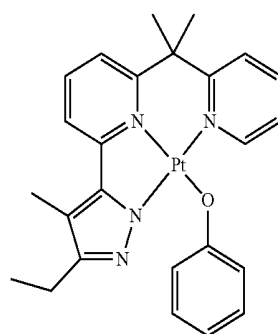
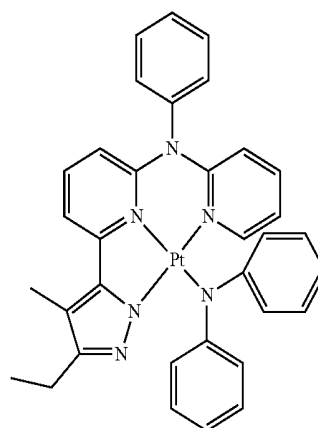
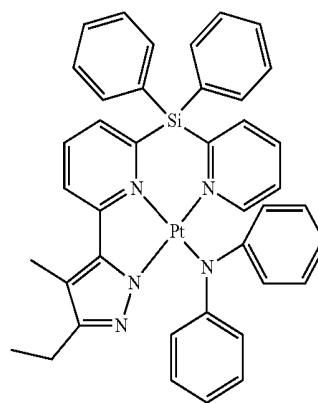
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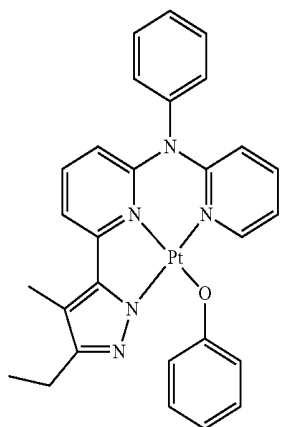
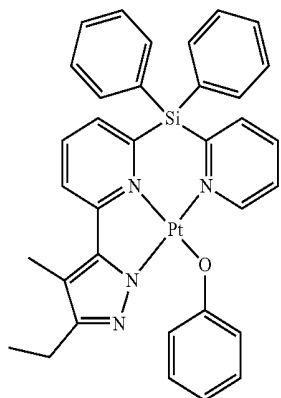
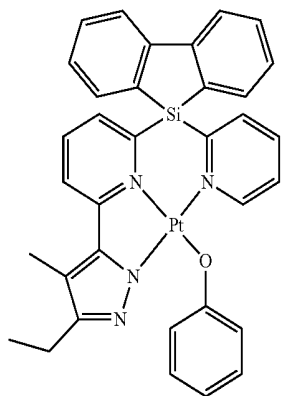
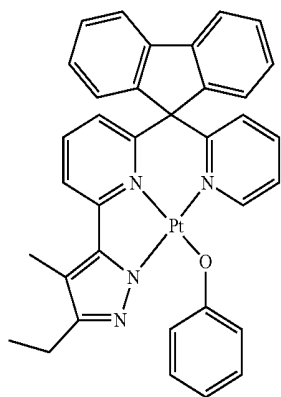
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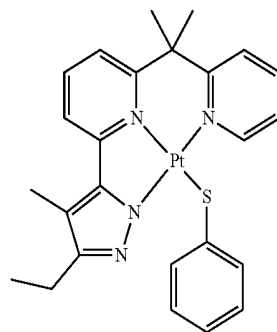
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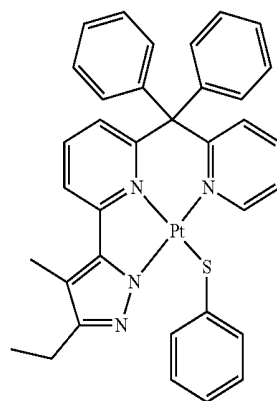


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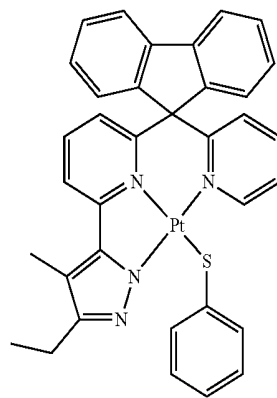


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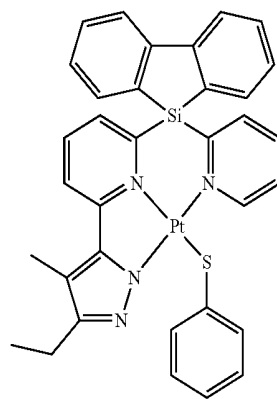
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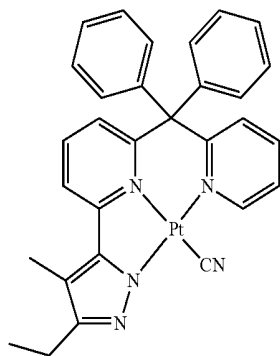
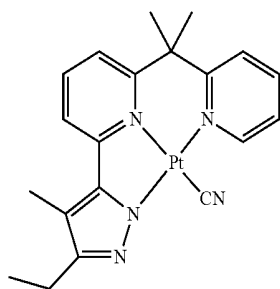
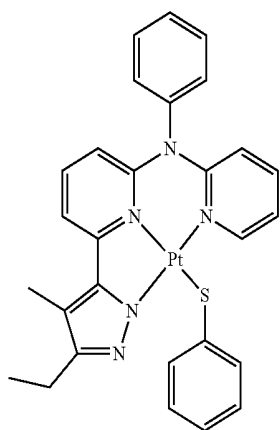
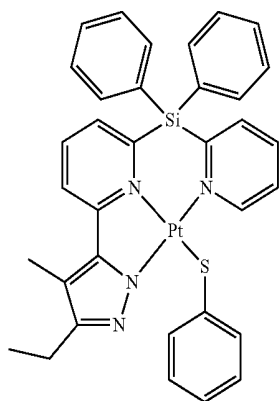
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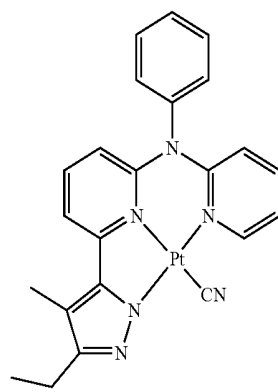
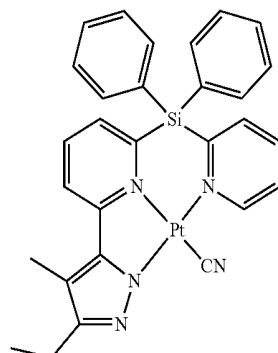
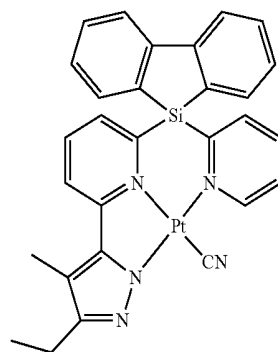
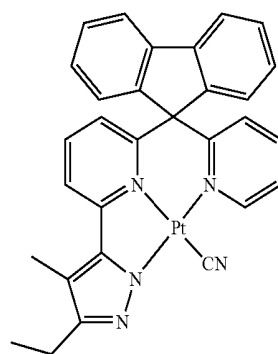
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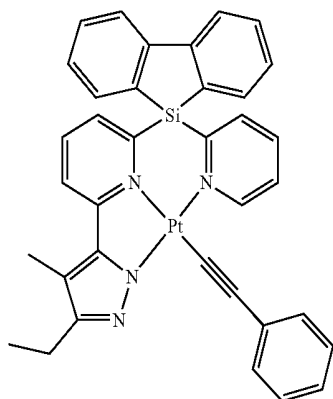
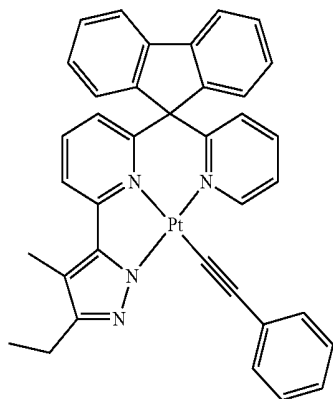
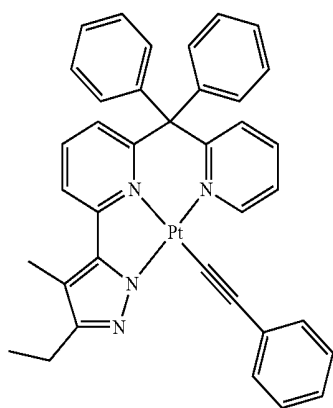
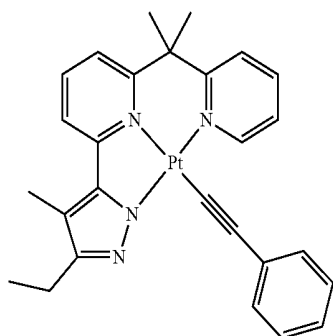


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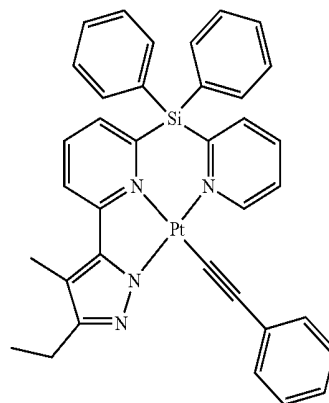
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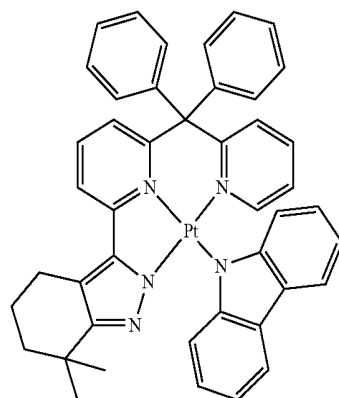
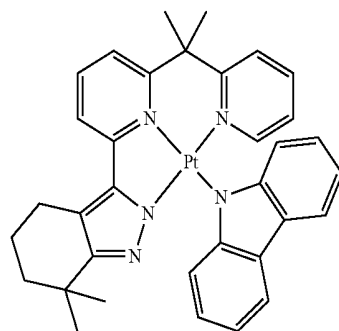
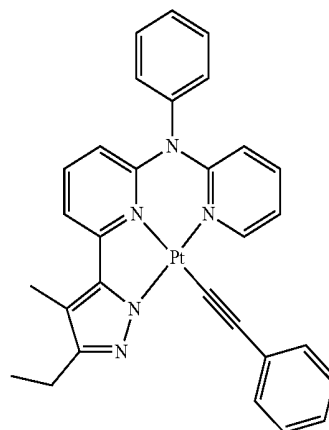
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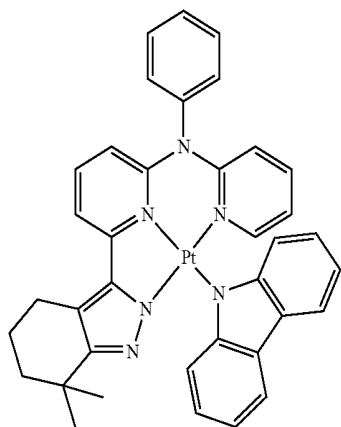
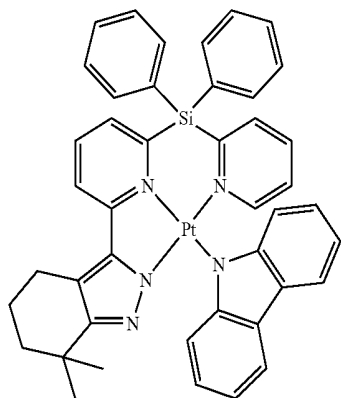
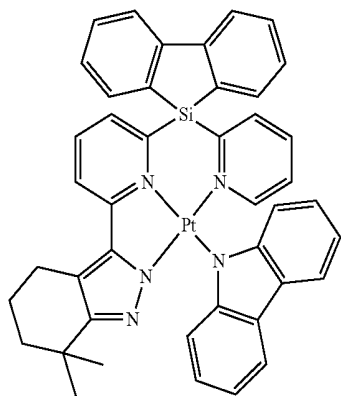
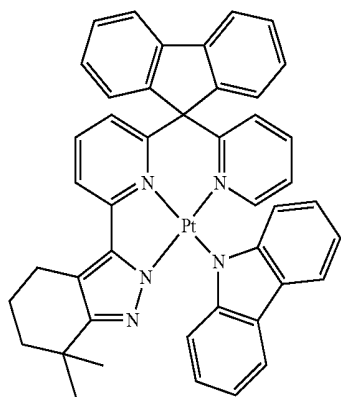
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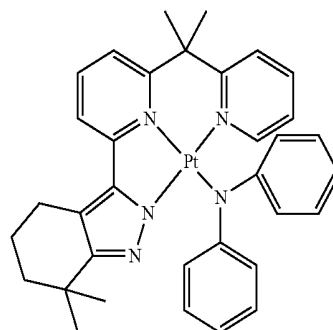
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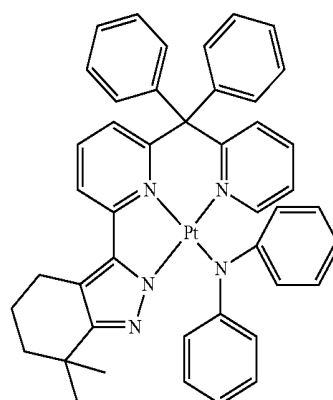
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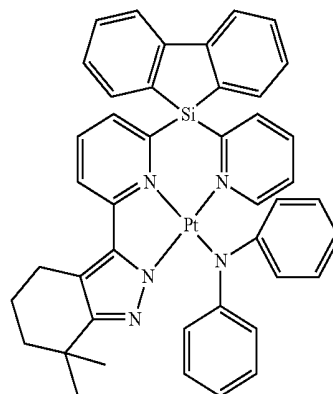
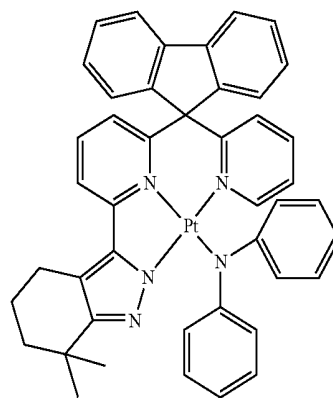
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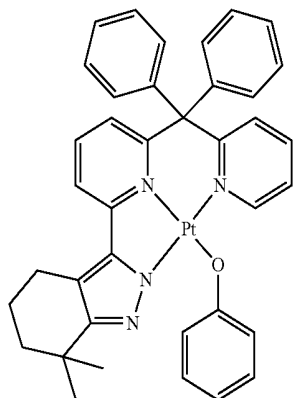
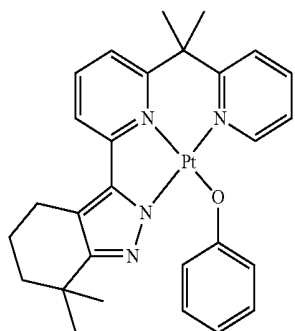
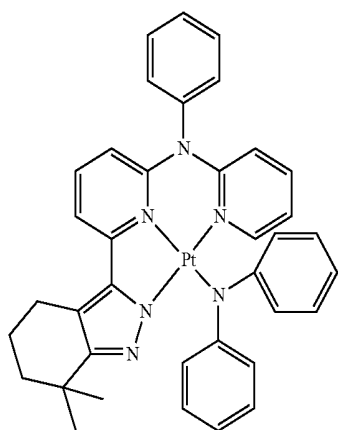
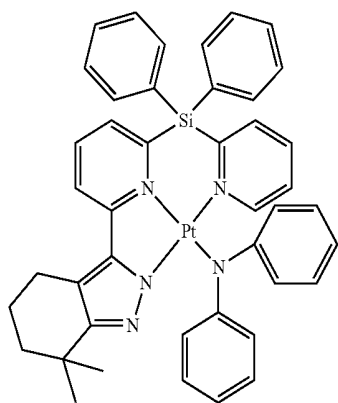
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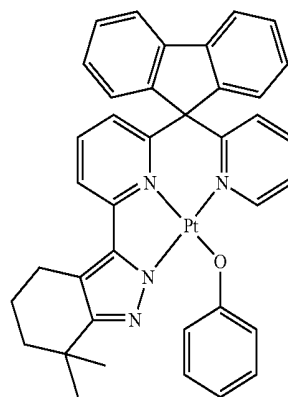
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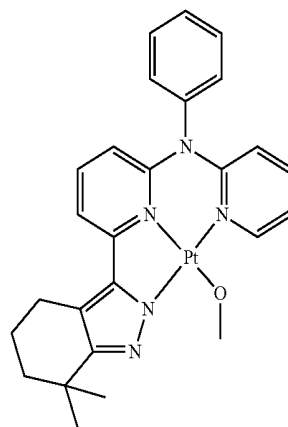
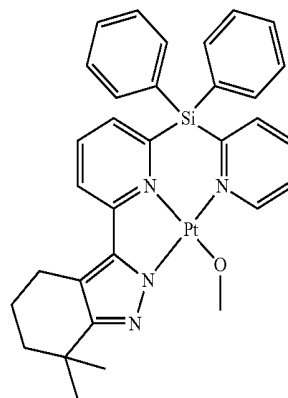
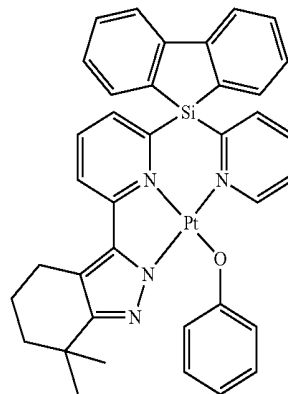
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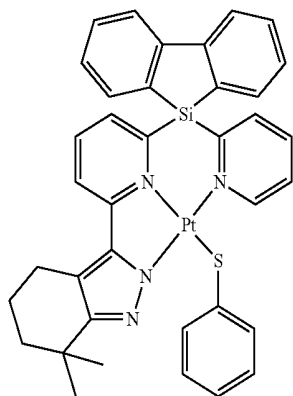
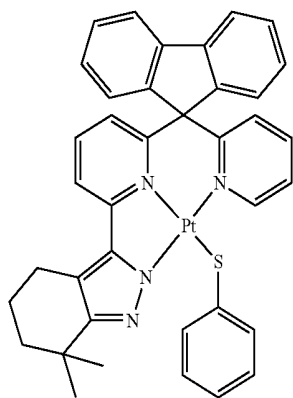
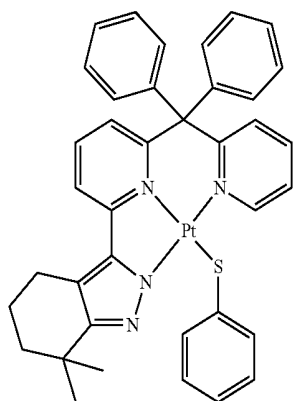
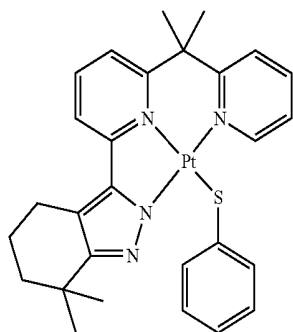
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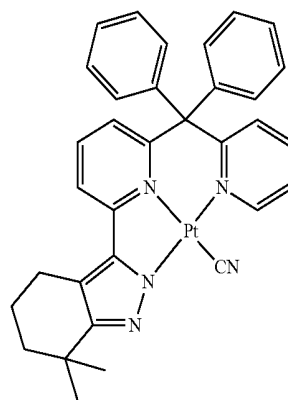
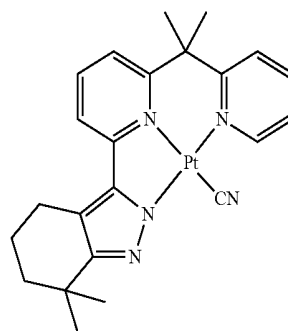
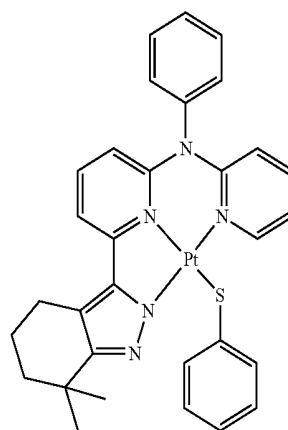
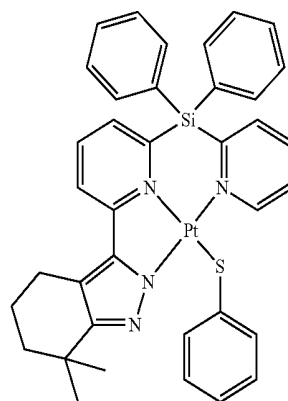
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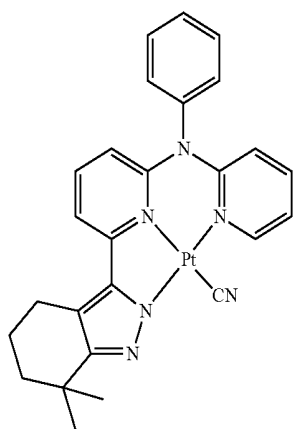
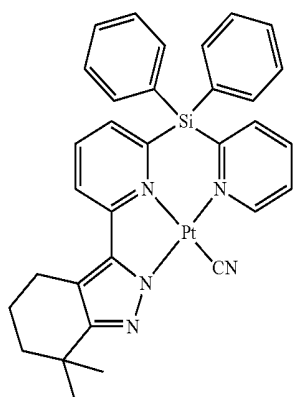
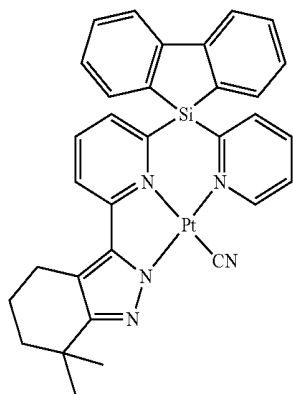
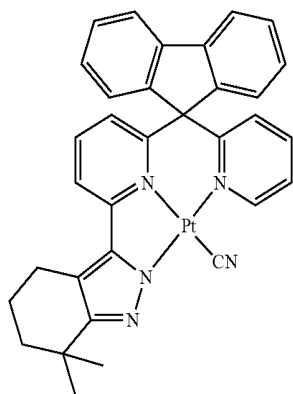
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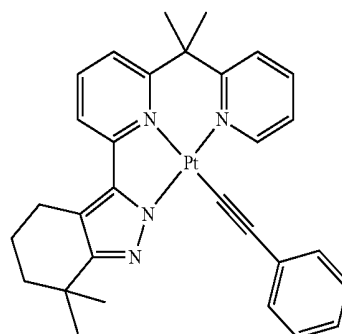
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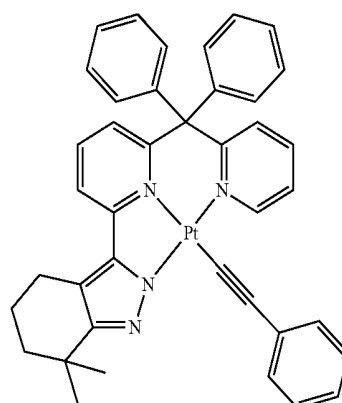
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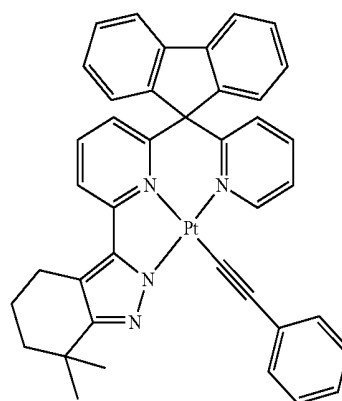


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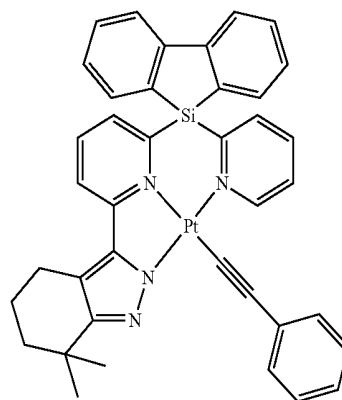


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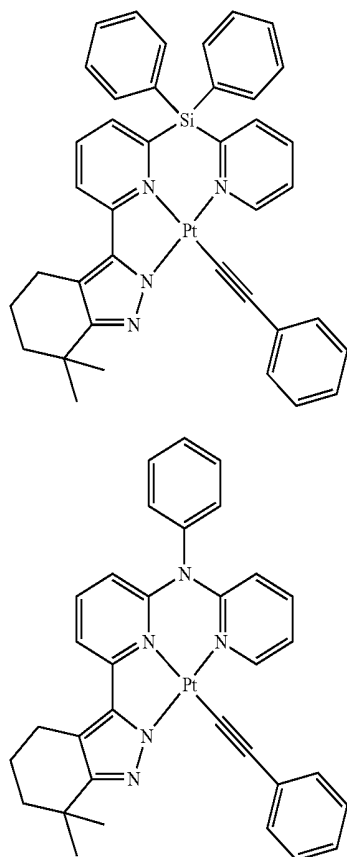
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11. An organic light-emitting device comprising:
a first electrode;
a negative electrode; and
an organic layer disposed between the first electrode and the second electrode, wherein the organic layer comprises an emission layer and at least one organometallic compound of claim 1.

12. The organic light-emitting device of claim 11, wherein the emission layer comprises the organometallic compound.

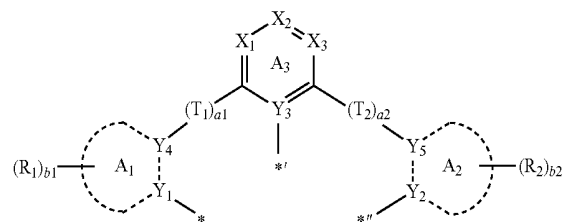
13. A composition for diagnosing comprising at least one organometallic compound of claim 1.

14. An organometallic compound represented by Formula 1:

$$M(L_1)(L_2)$$

Formula 1

Formula 2



wherein, in Formulae 1 and 2,

M is beryllium, magnesium, aluminum, calcium, titanium, manganese, cobalt, copper, zinc, gallium, germanium, zirconium, ruthenium, rhodium, palladium, silver, rhenium, gold, or platinum,

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L_1 is selected from tridentate ligands represented by Formula 2,

L_2 is selected from monodentate organic ligands, *, **, and *** in Formula 2 each indicate a binding site to M in Formula 1,

Y_1 to Y_3 are each nitrogen,

Y_4 and Y_5 are each carbon,

Y_1 is bound to Y_4 via a single or double bond, Y_2 is bound to Y_5 via a single or double bond,

provided that one selected from a bond between Y_1 and M, a bond between Y_2 and M, and a bond between ligand L_2 and M is a coordinate bond, while the rest are each a covalent bond,

a bond between Y_3 and M is a coordinate bond,

ring A_1 is a 5-membered ring comprising at least one nitrogen as a ring-forming atom,

ring A_2 is a 6-membered ring comprising at least one nitrogen as a ring-forming atom,

X_1 is N or C(R_3), X_2 is N or C(R_4), X_3 is N or C(R_5), at least two selected from R_3 to R_5 are optionally bound to each other to form a substituted or unsubstituted C_5 - C_{30} carbocyclic group or a substituted or unsubstituted C_2 - C_{30} heterocyclic group,

T_1 is a group selected from a single bond, $*-O-*$, $*-S-*$, $*-C(R_6)(R_7)-*$, $*-C(R_6)=*$, $*=C(R_6)-*$, $*-C(R_6)=C(R_7)-*$, $*-C(=O)-*$, $*-C(=S)-*$, $*-C\equiv C-*$, $*-N(R_6)-*$, $*-Si(R_6)(R_7)-*$, and $*-P(R_6)(R_7)-*$, wherein * and ** in each of the foregoing groups independently indicate a binding site to a neighboring atom,

T_2 is a group selected from $*-O-*$, $*-S-*$, $*-C(R_6)(R_7)-*$, $*-C(R_6)=*$, $*=C(R_6)-*$, $*-C(R_6)=C(R_7)-*$, $*-C(=O)-*$, $*-C(=S)-*$, $*-C\equiv C-*$, $*-N(R_6)-*$, $*-Si(R_6)(R_7)-*$, and $*-P(R_6)(R_7)-*$, wherein * and ** in each of the foregoing groups independently indicate a binding site to a neighboring atom,

R_6 and R_7 are optionally bound to each other to form a substituted or unsubstituted C_5 - C_{30} carbocyclic group or a substituted or unsubstituted C_2 - C_{30} heterocyclic group,

a_1 and a_2 are each independently an integer selected from 1 to 3, R_1 to R_7 are each independently selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, $-SF_5$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid 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, $-N(Q_1)(Q_2)$, $-Si(Q_3)(Q_4)(Q_5)$, $-B(Q_6)(Q_7)$, and $-P(=O)(Q_8)(Q_9)$,

b1 and b2 are each independently an integer selected from 0 to 3, and when b1 is 2 or greater, groups R₁ are identical to or different from each other, and when b2 is 2 or greater, groups R₂ are identical to or different from each other,

two of the b1 number of groups R₁ are optionally bound to each other to form a substituted or unsubstituted C₅-C₃₀ carbocyclic group or a substituted or unsubstituted C₂-C₃₀ heterocyclic group,

two of the b2 number of groups R₂ are optionally bound to each other to form a substituted or unsubstituted C₅-C₃₀ carbocyclic group or a substituted or unsubstituted C₂-C₃₀ heterocyclic group,

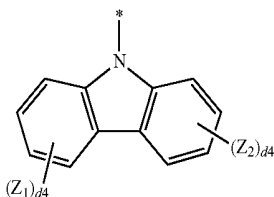
provided that,

i) T₂ is a group selected from *—C(R₆)(R₇)—* and *—Si(R₆)(R₇)—* and R₆ and R₇ are bound to each other to form a substituted or unsubstituted C₅-C₃₀ carbocyclic group or a substituted or unsubstituted C₂-C₃₀ heterocyclic group,

ii) L₂ is a monodentate organic ligand represented by Formula 13-47 or

iii) T₂ is a group selected from *—C(R₆)(R₇)—* and *—Si(R₆)(R₇)—* and R₆ and R₇ are bound to each other to form a substituted or unsubstituted C₅-C₃₀ carbocyclic group or a substituted or unsubstituted C₂-C₃₀ heterocyclic group; and L₂ is a monodentate organic ligand represented by Formula 13-47,

Formula 13-47



wherein, in Formulae 13-47,

Z₁ and Z₂ are each independently selected from hydrogen, deuterium, —F, a cyano group, a nitro group, —SF₅, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an iso-hexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an iso-heptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an iso-octyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an iso-nonyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an iso-decyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

and a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, an iso-butyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an iso-pentyl group, a sec-pentyl group, a tert-pentyl

group, an n-hexyl group, an iso-hexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an iso-heptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an iso-octyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an iso-nonyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an iso-decyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, —F, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, a cyano group, a nitro group, a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

d4 is an integer selected from 1 to 4,

* indicates a binding site to M in Formula 1,

at least one of substituents of the substituted C₅-C₃₀ carbocyclic group, substituted C₂-C₃₀ heterocyclic group, substituted C₁-C₆₀ alkyl group, substituted C₂-C₆₀ alkenyl group, substituted C₂-C₆₀ alkynyl group, substituted C₁-C₆₀ alkoxy group, substituted C₃-C₁₀ cycloalkyl group, substituted C₁-C₁₀ heterocycloalkyl group, substituted C₃-C₁₀ cycloalkenyl group, substituted C₁-C₁₀ heterocycloalkenyl group, substituted C₆-C₆₀ aryl group, substituted C₆-C₆₀ aryloxy group, substituted C₆-C₆₀ arylthio group, substituted C₁-C₆₀ heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic condensed heteropolycyclic group is selected from:

deuterium, —F, —Cl, —Br, —I, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, 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 deuterium, —F, —Cl, —Br, —I, —CD₃, —CD₂H, —CDH₂, —CF₃, —CF₂H, —CFH₂, 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 con-

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- densed heteropolycyclic group, $-\text{N}(\text{Q}_{11})(\text{Q}_{12})$, $-\text{Si}(\text{Q}_{13})(\text{Q}_{14})(\text{Q}_{15})$, $-\text{B}(\text{Q}_{16})(\text{Q}_{17})$, and $-\text{P}(=\text{O})(\text{Q}_{18})(\text{Q}_{19})$;
- a $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, a $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_6\text{-C}_{60}$ aryloxy group, a $\text{C}_6\text{-C}_{60}$ arylthio group, a $\text{C}_1\text{-C}_{60}$ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;
- a $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, a $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_6\text{-C}_{60}$ aryloxy group, a $\text{C}_6\text{-C}_{60}$ arylthio group, a $\text{C}_1\text{-C}_{60}$ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, $-\text{CD}_3$, $-\text{CD}_2\text{H}$, $-\text{CDH}_2$, $-\text{CF}_3$, $-\text{CF}_2\text{H}$, $-\text{CFH}_2$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a $\text{C}_1\text{-C}_{60}$ alkyl group, a $\text{C}_2\text{-C}_{60}$ alkenyl group, a $\text{C}_2\text{-C}_{60}$ alkynyl group, a $\text{C}_1\text{-C}_{60}$ alkoxy group, a $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, a $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_6\text{-C}_{60}$ aryl group substituted with at least one selected from a $\text{C}_1\text{-C}_{60}$ alkyl group and a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_6\text{-C}_{60}$ aryloxy group, a $\text{C}_6\text{-C}_{60}$ arylthio group, a $\text{C}_1\text{-C}_{60}$ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

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- aryl group, a $\text{C}_6\text{-C}_{60}$ aryloxy group, a $\text{C}_6\text{-C}_{60}$ arylthio group, a $\text{C}_1\text{-C}_{60}$ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $-\text{N}(\text{Q}_{21})(\text{Q}_{22})$, $-\text{Si}(\text{Q}_{23})(\text{Q}_{24})(\text{Q}_{25})$, $-\text{B}(\text{Q}_{26})(\text{Q}_{27})$, and $-\text{P}(=\text{O})(\text{Q}_{28})(\text{Q}_{29})$; and $-\text{N}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{Si}(\text{Q}_{33})(\text{Q}_{34})(\text{Q}_{35})$, $-\text{B}(\text{Q}_{36})(\text{Q}_{37})$, and $-\text{P}(=\text{O})(\text{Q}_{38})(\text{Q}_{39})$,
- wherein Q_1 to Q_9 , Q_{11} to Q_{19} , Q_{21} to Q_{29} , and Q_{31} to Q_{39} are each independently selected from hydrogen, deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, 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, a $\text{C}_1\text{-C}_{60}$ alkyl group, a $\text{C}_2\text{-C}_{60}$ alkenyl group, a $\text{C}_2\text{-C}_{60}$ alkynyl group, a $\text{C}_1\text{-C}_{60}$ alkoxy group, a $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, a $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_6\text{-C}_{60}$ aryl group substituted with at least one selected from a $\text{C}_1\text{-C}_{60}$ alkyl group and a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_6\text{-C}_{60}$ aryloxy group, a $\text{C}_6\text{-C}_{60}$ arylthio group, a $\text{C}_1\text{-C}_{60}$ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

* * * * *

专利名称(译)	有机金属化合物，有机发光装置以及用于诊断的组合物包括有机金属化合物		
公开(公告)号	US10529935	公开(公告)日	2020-01-07
申请号	US15/218714	申请日	2016-07-25
[标]申请(专利权)人(译)	三星电子株式会社		
申请(专利权)人(译)	SAMSUNG ELECTRONICS CO. , LTD.		
当前申请(专利权)人(译)	SAMSUNG ELECTRONICS CO. , LTD.		
[标]发明人	LEE JIYOUN KWAK YOONHYUN KWON OHYUN LEE SUNYOUNG CHOI HYEONHO KIM JIWHAN		
发明人	LEE, JIYOUN KWAK, YOONHYUN KWON, OHYUN LEE, SUNYOUNG CHOI, HYEONHO KIM, JIWHAN		
IPC分类号	H01L51/00 C07F15/00 C09K11/06 H01L51/50		
CPC分类号	C07F15/0086 C09K11/06 H01L51/0094 H01L51/0087 H01L51/5016 C09K2211/1044 C09K2211/1011 C09K2211/185 C09K2211/1007 C09K2211/1096		
代理机构(译)	康托科尔伯恩LLP		
优先权	1020160015675 2016-02-11 KR		
其他公开文献	US20170237022A1		
外部链接	Espacenet		

摘要(译)

式1表示的有机金属化合物： $M(L1)(L2)$ 公式1 其中，在式1中，M，L1和L2相同 如规范中所述。

