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

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(57) **ABSTRACT**

An organometallic compound and an organic light-emitting device including the same are provided. The organometallic compound is represented by Formula 1 below:

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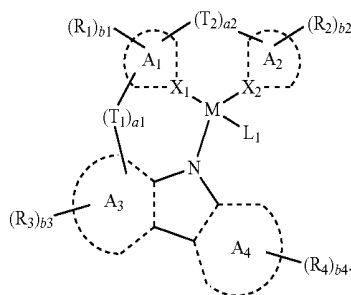
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Formula 1



10

190
150
110

FIG. 1

10

190
150
110

FIG. 2

20

190
150
110
210

FIG. 3

30

220
190
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110

FIG. 4

40

220
190
150
110
210

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

CROSS-REFERENCE TO RELATED
APPLICATION

[0001] This application claims priority to and the benefit of Korean Patent Application No. 10-2017-0128295, filed on Sep. 29, 2017, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein in its entirety by reference.

BACKGROUND

1. Field

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

2. Description of the Related Art

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

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

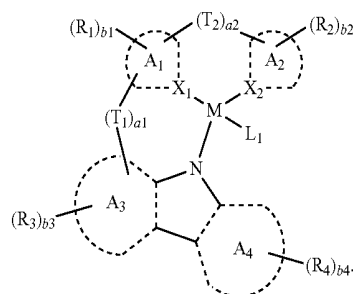
[0005] The organic light-emitting devices may be applied to a variety of devices, for example, an authentication device or an electronic device.

SUMMARY

[0006] Aspects of the present disclosure are directed toward an organic light-emitting device capable of emitting light of a near-infrared (NIR) region while having a low driving voltage, a high efficiency, and a long lifespan, and an organic light-emitting apparatus including the organic light-emitting device.

[0007] 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.

[0008] According to an embodiment of the present disclosure, an organometallic compound is represented by Formula 1 below:



Formula 1

[0009] In Formula 1,

[0010] M is a transition metal;

[0011] L₁ may be a monovalent organic ligand;

[0012] two bonds selected from a bond between X₁ and M, a bond between X₂ and M, and a bond between L₁ and M may each be a coordinate bond, and a third bond thereof may be a covalent bond;

[0013] X₁ and X₂ may each independently be N or C;

[0014] A₁ to A₄ may each independently be a C₅-C₃₀ carbocyclic group or a C₁-C₆₀ heterocyclic group;

[0015] T₁ and T₂ may each independently be selected from *—N[(L₁₁)_{a11}—(R₁₁)_{b11}]*, *—B(R₁₁)—*, *—P(R₁₁)—*, *—C(R₁₁)(R₁₂)—*, *—Si(R₁₁)(R₁₂)—*, *—Ge(R₁₁)(R₁₂)—*, *—S—*, *—Se—*, *—O—*, *—C(=O)—*, *—S(=O)—*, *—S(=O)₂—*, *—C(R₁₁)=*, *—C(R₁₁)—*, *—C(R₁₁)=C(R₁₂)—*, *—C(=S)—*, and *—C≡C—*;

[0016] L₁₁ may be a single bond, a substituted or unsubstituted C₅-C₃₀ carbocyclic group, or a substituted or unsubstituted C₁-C₆₀ heterocyclic group;

[0017] a₁₁ may be an integer from 0 to 3, wherein, when a₁₁ is zero, *(L₁₁)_{a11}* may be a single bond;

[0018] when a₁₁ is two or more, two or more L₁₁(s) may be identical to or different from each other;

[0019] R₁₁ and R₁₂ may optionally be linked to a neighboring substituent in R₁ to R₃ to form a substituted or unsubstituted C₅-C₃₀ carbocyclic group or a substituted or unsubstituted C₁-C₆₀ heterocyclic group;

[0020] a₁ and a₂ may each independently be 0, 1, 2, or 3, wherein, when a₁ is zero, *(T₁)_{a1}* may be a single bond, and when a₂ is zero, *(T₂)_{a2}* may be a single bond;

[0021] when a₁ is two or more, two or more T₁(s) may be identical to or different from each other, and when a₂ is two or more, two or more T₂(s) may be identical to or different from each other;

[0022] R₁ to R₄, R₁₁, and R₁₂ may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted 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 het-

eroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, $-\text{Si}(\text{Q}_1)(\text{Q}_2)(\text{Q}_3)$, $-\text{N}(\text{Q}_1)(\text{Q}_2)$, $-\text{B}(\text{Q}_1)(\text{Q}_2)$, $-\text{C}(=\text{O})(\text{Q}_1)$, $-\text{S}(=\text{O})_2(\text{Q}_1)$, and $-\text{P}(=\text{O})(\text{Q}_1)(\text{Q}_2)$;

[0023] neighboring substituents in R_1 to R_4 may optionally be linked to form a substituted or unsubstituted $\text{C}_5\text{-C}_{30}$ carbocyclic group or a substituted or unsubstituted $\text{C}_1\text{-C}_{60}$ heterocyclic group;

[0024] b_1 to b_4 and b_{11} may each independently be an integer from 1 to 6, wherein, when b_1 is two or more, two or more $\text{R}_1(\text{s})$ may be identical to or different from each other, when b_2 is two or more, two or more $\text{R}_2(\text{s})$ may be identical to or different from each other, when b_3 is two or more, two or more $\text{R}_3(\text{s})$ may be identical to or different from each other, when b_4 is two or more, two or more $\text{R}_4(\text{s})$ may be identical to or different from each other, and when b_{11} is two or more, two or more $\text{R}_{11}(\text{s})$ may be identical to or different from each other;

[0025] at least one substituent of the substituted $\text{C}_5\text{-C}_{30}$ carbocyclic group, the substituted $\text{C}_1\text{-C}_{60}$ heterocyclic group, the substituted $\text{C}_1\text{-C}_{60}$ alkyl group, the substituted $\text{C}_2\text{-C}_{60}$ alkenyl group, the substituted $\text{C}_2\text{-C}_{60}$ alkynyl group, the substituted $\text{C}_1\text{-C}_{60}$ alkoxy group, the substituted $\text{C}_3\text{-C}_{10}$ cycloalkyl group, the substituted $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, the substituted $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, the substituted $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, the substituted $\text{C}_6\text{-C}_{60}$ aryl group, the substituted $\text{C}_6\text{-C}_{60}$ aryloxy group, the substituted $\text{C}_6\text{-C}_{60}$ arylthio group, the substituted $\text{C}_1\text{-C}_{60}$ heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from:

[0026] deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, 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, and a $\text{C}_1\text{-C}_{60}$ alkoxy group;

[0027] 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, and a $\text{C}_1\text{-C}_{60}$ alkoxy group, each substituted with at least one selected from deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono 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, a monovalent non-aromatic condensed heteropolycyclic group, $-\text{Si}(\text{Q}_{11})(\text{Q}_{12})(\text{Q}_{13})$, $-\text{N}(\text{Q}_{11})(\text{Q}_{12})$, $-\text{B}(\text{Q}_{11})(\text{Q}_{12})$, $-\text{C}(=\text{O})(\text{Q}_{11})$, $-\text{S}(=\text{O})_2(\text{Q}_{11})$, and $-\text{P}(=\text{O})(\text{Q}_{11})(\text{Q}_{12})$;

[0028] 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, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group;

[0029] 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, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, 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 $\text{C}_6\text{-C}_{60}$ 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, $-\text{Si}(\text{Q}_{21})(\text{Q}_{22})(\text{Q}_{23})$, $-\text{N}(\text{Q}_{21})(\text{Q}_{22})$, $-\text{B}(\text{Q}_{21})(\text{Q}_{22})$, $-\text{C}(=\text{O})(\text{Q}_{21})$, $-\text{S}(=\text{O})_2(\text{Q}_{21})$, and $-\text{P}(=\text{O})(\text{Q}_{21})(\text{Q}_{22})$; and

[0030] $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, $-\text{N}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{B}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{C}(=\text{O})(\text{Q}_{31})$, $-\text{S}(=\text{O})_2(\text{Q}_{31})$, and $-\text{P}(=\text{O})(\text{Q}_{31})(\text{Q}_{32})$; and

[0031] Q_1 to Q_3 , Q_{11} to Q_{13} , Q_{21} to Q_{23} , and Q_{31} to Q_{33} may each independently be selected from hydrogen, deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, 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 $\text{C}_1\text{-C}_{60}$ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

[0032] According to another embodiment of the present disclosure, an organic light-emitting device includes: a first electrode; a second electrode facing the first electrode; and an organic layer between the first electrode and the second electrode, the organic layer including an emission layer and at least one of the organometallic compound.

[0033] According to another embodiment of the present disclosure, an apparatus includes the organic light-emitting device. The apparatus may be, for example, a light-emitting device, an authentication apparatus, or an electronic apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034] 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:

[0035] FIG. 1 is a schematic view of an organic light-emitting device according to an embodiment;

[0036] FIG. 2 is a schematic view of an organic light-emitting device according to an embodiment;

[0037] FIG. 3 is a schematic view of an organic light-emitting device according to an embodiment; and

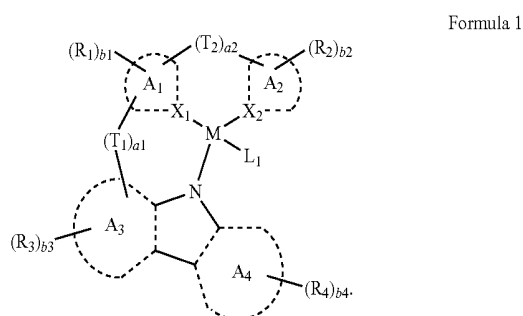
[0038] FIG. 4 is a schematic view of an organic light-emitting device according to an embodiment.

DETAILED DESCRIPTION

[0039] 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, so that this disclosure will be thorough and complete, and will fully convey the scope of the inventive concept to those skilled in the art. 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.

[0040] An organometallic compound according to an embodiment is represented by Formula 1 below:



[0041] M in Formula 1 may be a transition metal. The term “transition metal” as used herein refers to elements belonging to groups 3 to 12 in the periodic table.

[0042] In one embodiment, M in Formula 1 may be selected from Zn, Cu, Pt, and Pd, but embodiments of the present disclosure are not limited thereto. For example, M in Formula 1 may be Pt or Pd.

[0043] In Formula 1, two bonds selected from a bond between X₁ and M, a bond between X₂ and M, and a bond between L₁ and M may each be a coordinate bond, and the other (i.e., a third bond) thereof may be a covalent bond.

[0044] In one embodiment, the bond between X₁ and M and the bond between X₂ and M may each be a coordinate bond, and the bond between L₁ and M may be a covalent bond, but embodiments of the present disclosure are not limited thereto.

[0045] For example, the bond between X₁ and M and the bond between L₁ and M may each be a coordinate bond, and the bond between X₂ and M may be a covalent bond. For example, the bond between X₂ and M and the bond between L₁ and M may each be a coordinate bond, and the bond between X₁ and M may be a covalent bond.

[0046] X₁ and X₂ in Formula 1 may each independently be N or C.

[0047] In one embodiment, in Formula 1, X₁ and X₂ may each be N, and the bond between X₁ and M and the bond between X₂ and M may each be a coordinate bond, but embodiments of the present disclosure are not limited thereto.

[0048] For example, in Formula 1, X₁ may be C, X₂ may be N, the bond between X₁ and M may be a covalent bond, and the bond between X₂ and M may be a coordinate bond. For example, X₁ may be N, X₂ may be C, the bond between X₁ and M may be a coordinate bond, and the bond between X₂ and M may be a covalent bond.

[0049] A₁ to A₄ in Formula 1 may each independently be a C₅-C₃₀ carbocyclic group or a C₁-C₆₀ heterocyclic group.

[0050] In one embodiment, A₁ to A₄ in Formula 1 may each independently be selected from:

[0051] a benzene group, a naphthalene group, an anthracene group, a phenanthrene group, a phenalene group, a tetracene group, a chrysene group, a pyrene group, a fluoranthene group, a triphenylene group, a fluorene group, a benzofluorene group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, an indole group, an iso-indole group, an indazole group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, a naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a carbazole group, a phenanthridine group, an acridine group, a phenanthroline group, a phenazine group, a benzimidazole group, a triazine group, a benzocarbazole group, and a dibenzocarbazole group, but embodiments of the present disclosure are not limited thereto.

[0052] For example, A₁ to A₄ may each independently be selected from a benzene group, a naphthalene group, a pyridine group, a pyrimidine group, a pyrazine group, a triazine group, a quinoline group, and an isoquinoline group.

[0053] In one embodiment, A₁ to A₄ may be identical to or different from each other.

[0054] For example, A₁ and A₂ may be identical to each other. For example, A₁ and A₂ may be different from each other. For example, A₃ and A₄ may be identical to each other. For example, A₃ and A₄ may be different from each other. For example, A₁ may be different from A₃ and A₄. For example, A₂ may be different from A₃ and A₄.

[0055] In one embodiment, A₁ and A₂ may each independently be selected from a pyridine group, a pyridine group, a pyrimidine group, a pyrazine group, a triazine group, a quinoline group, and an isoquinoline group.

[0056] A₃ and A₄ may each independently be a benzene group or a naphthalene group, but embodiments of the present disclosure are not limited thereto.

[0057] T₁ and T₂ in Formula 1 may each independently be selected from *—N[(L₁₁)_{a11}—(R₁₁)_{b11}]*, *—B(R₁₁)—*, *—P(R₁₁)—*, *—C(R₁₁)(R₁₂)—*, *—Si(R₁₁)(R₁₂)—*, *—Ge(R₁₁)(R₁₂)—*, *—S—*, *—Se—*, *—O—*, *—C(=O)—*, *—S(=O)—*, *—S(=O)₂—*, *—C(R₁₁)=*, *—C(R₁₁)—*, *—C(R₁₁)=C(R₁₂)—*, *—C(=S)—*, and *—C≡C—*.

[0058] L₁₁ may be a substituted or unsubstituted C₅-C₃₀ carbocyclic group or a substituted or unsubstituted C₁-C₆₀ heterocyclic group.

[0059] In one embodiment, L₁₁ may be selected from:

[0060] a benzene group, a naphthalene group, a pyrrole group, a thiophene group, a furan group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an indole group, an iso-indole group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a benzimidazole group, a benzofuran group, a benzothiophene group, an iso-benzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, and a triazine group; and

[0061] a benzene group, a naphthalene group, a pyrrole group, a thiophene group, a furan group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a

pyrazine group, a pyrimidine group, a pyridazine group, an indole group, an iso-indole group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a benzimidazole group, a benzofuran group, a benzothiophene group, an iso-benzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, and a triazine group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl 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 indolyl group, an isoindolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a benzimidazolyl 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, and a triazinyl group, but embodiments of the present disclosure are not limited thereto.

[0062] a11 may be selected from 0 to 3, wherein, when a11 is zero, $^{*-(L_{11})_{a11}-^{*}}$ may be a single bond.

[0063] When a11 is two or more, two or more L₁₁(s) may be identical to or different from each other.

[0064] R₁₁ and R₁₂ may optionally be linked to a neighboring substituent in R₁ to R₃ to form a substituted or unsubstituted C₅-C₃₀ carbocyclic group or a substituted or unsubstituted C₁-C₆₀ heterocyclic group.

[0065] a1 and a2 in Formula 1 may each independently be 0, 1, 2, or 3, wherein, when a1 is zero, $^{*-(T_1)_{a1}-^{*}}$ may be a single bond, and when a2 is zero, $^{*-(T_2)_{a2}-^{*}}$ may be a single bond.

[0066] When a1 is two or more, two or more T₁(s) may be identical to or different from each other, and when a2 is two or more, two or more T₂(s) may be identical to or different from each other.

[0067] R₁ to R₄, R₁₁, and R₁₂ in Formula 1 may each independently be selected from:

[0068] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₂-C₆₀ alkenyl group, a substituted or unsubstituted C₂-C₆₀ alkylnyl 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 C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed het-

eropolycyclic group, —Si(Q₁)(Q₂)(Q₃), —N(Q₁)(Q₂), —B(Q₁)(Q₂), —C(=O)(Q₁), —S(=O)₂(Q₁), and —P(=O)(Q₁)(Q₂).

[0069] In one embodiment, R₁ to R₄, R₁₁, and R₁₂ in Formula 1 may each independently be selected from:

[0070] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₂-C₂₀ alkenyl group, a C₂-C₂₀ alkylnyl group, and a C₁-C₂₀ alkoxy group;

[0071] a C₁-C₂₀ alkyl group and a C₁-C₂₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, and a C₁-C₂₀ alkoxy group;

[0072] a cyclopentyl group, a cyclohexyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, an anthracenyl group, a phenanthrenyl group, a phenalenyl group, a tetracenyl group, a chrysenyl group, a pyrenyl group, a fluoranthenyl group, a triphenylenyl group, a fluorenyl group, a benzofluorenyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, an indolyl group, an isoindolyl group, an indazolyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a dibenzofuranlyl group, a dibenzothiophenyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a triazinyl group, a benzo-carbazolyl group, and a dibenzocarbazolyl group; and

[0073] a cyclopentyl group, a cyclohexyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, an anthracenyl group, a phenanthrenyl group, a phenalenyl group, a tetracenyl group, a chrysenyl group, a pyrenyl group, a fluoranthenyl group, a triphenylenyl group, a fluorenyl group, a benzofluorenyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, an indolyl group, an isoindolyl group, an indazolyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a dibenzofuranlyl group, a dibenzothiophenyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a triazinyl group, a benzo-carbazolyl group, and a dibenzocarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, an anthracenyl group, a phenanthrenyl group, a phenalenyl group, a tetracenyl group, a chrysenyl group, a pyrenyl group, a fluoranthenyl group, a triphenylenyl group, a fluorenyl group, a benzofluorenyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, an indolyl group, an isoindolyl group, an indazolyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a dibenzofuranlyl group, a diben-

zothiophenyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a triazinyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, $-\text{N}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{B}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{C}(=\text{O})(\text{Q}_{31})$, $-\text{S}(=\text{O})_2(\text{Q}_{31})$, and $-\text{P}(=\text{O})(\text{Q}_{31})(\text{Q}_{32})$; and

[0074] $-\text{Si}(\text{Q}_1)(\text{Q}_2)(\text{Q}_3)$, $-\text{N}(\text{Q}_1)(\text{Q}_2)$, $-\text{B}(\text{Q}_1)(\text{Q}_2)$, $-\text{C}(=\text{O})(\text{Q}_1)$, $-\text{S}(=\text{O})_2(\text{Q}_1)$, and $-\text{P}(=\text{O})(\text{Q}_1)(\text{Q}_2)$, but embodiments of the present disclosure are not limited thereto.

[0075] Q_1 to Q_3 and Q_{31} to Q_{33} may each independently be selected from:

[0076] hydrogen, deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a cyano group, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, a C_1 - C_{20} alkoxy group, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{20} aryl group, a C_1 - C_{20} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, but embodiments of the present disclosure are not limited thereto.

[0077] For example, R_1 to R_4 , R_{11} , and R_{12} in Formula 1 may each independently be selected from:

[0078] hydrogen, deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, and a C_1 - C_{20} alkoxy group;

[0079] a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group, each substituted with at least one selected from deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

[0080] a phenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, an indolyl group, an isoindolyl group, an indazolyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a benzimidazolyl group; and

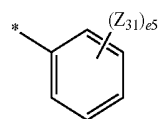
[0081] a phenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, an indolyl group, an isoindolyl group, an indazolyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a benzimidazolyl group, each substituted with at least one selected from deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, an indolyl group, an isoindolyl group, an indazolyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzimidazolyl

group, $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, $-\text{N}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{B}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{C}(=\text{O})(\text{Q}_{31})$, $-\text{S}(=\text{O})_2(\text{Q}_{31})$, and $-\text{P}(=\text{O})(\text{Q}_{31})(\text{Q}_{32})$; and

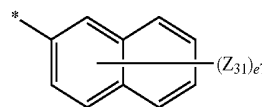
[0082] $-\text{Si}(\text{Q}_1)(\text{Q}_2)(\text{Q}_3)$, $-\text{N}(\text{Q}_1)(\text{Q}_2)$, $-\text{B}(\text{Q}_1)(\text{Q}_2)$, $-\text{C}(=\text{O})(\text{Q}_1)$, $-\text{S}(=\text{O})_2(\text{Q}_1)$, and $-\text{P}(=\text{O})(\text{Q}_1)(\text{Q}_2)$, and

[0083] Q_1 to Q_3 and Q_{31} to Q_{33} may each independently be selected from hydrogen, deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a cyano group, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, a C_1 - C_{20} alkoxy group, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{20} aryl group, a C_1 - C_{20} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

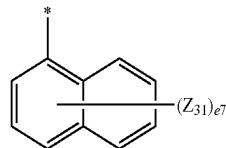
[0084] For example, R_1 to R_4 , R_{11} , and R_{12} may each independently be selected from hydrogen, deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_2 - C_{20} alkenyl group, a C_2 - C_{20} alkynyl group, a C_1 - C_{20} alkoxy group, and groups represented by Formulae 5-1 to 5-16:



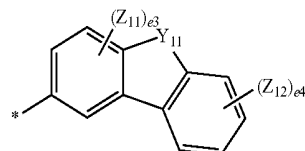
Formula 5-1



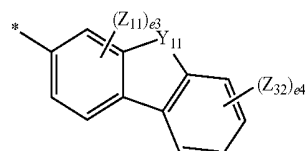
Formula 5-2



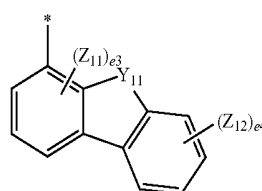
Formula 5-3



Formula 5-4

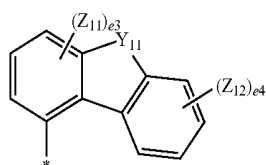


Formula 5-5

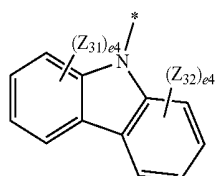


Formula 5-6

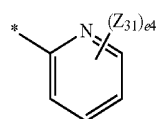
-continued



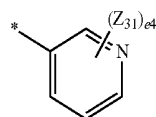
Formula 5-7



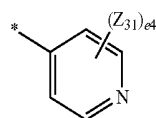
Formula 5-8



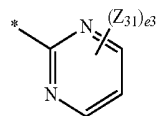
Formula 5-9



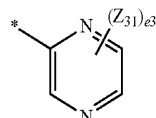
Formula 5-10



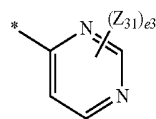
Formula 5-11



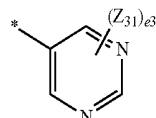
Formula 5-12



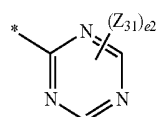
Formula 5-13



Formula 5-14



Formula 5-15



Formula 5-16

[0085] In Formulae 5-1 to 5-16,

[0086] Y_{31} may be O, S, $C(Z_{33})(Z_{34})$, $N(Z_{35})$, or $Si(Z_{36})(Z_{37})$,

[0087] Z_{31} to Z_{37} may each independently be selected from:

[0088] hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl

group, a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a phenyl group, a biphenyl group, a terphenyl group, a fluorenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a carbazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group,

[0089] e_2 may be an integer from 0 to 2,

[0090] e_3 may be an integer from 0 to 3,

[0091] e_4 may be an integer from 0 to 4,

[0092] e_5 may be an integer from 0 to 5,

[0093] e_6 may be an integer from 0 to 6,

[0094] e_7 may be an integer from 0 to 7, and

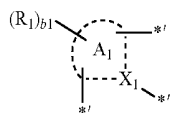
[0095] * indicates a binding site to a neighboring atom.

[0096] Neighboring substituents in R_1 to R_4 in Formula 1 may optionally be linked to form a substituted or unsubstituted C_5 - C_{30} carbocyclic group or a substituted or unsubstituted C_1 - C_{60} heterocyclic group.

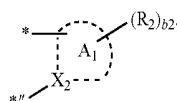
[0097] In one embodiment, when two or more $R_1(s)$ are present, two or more neighboring $R_1(s)$ may be linked to form a substituted or unsubstituted C_5 - C_{30} carbocyclic group or a substituted or unsubstituted C_1 - C_{60} heterocyclic group. Similarly, when two or more $R_2(s)$, $R_3(s)$, or $R_4(s)$ are present, two or more neighboring $R_2(s)$, $R_3(s)$, or $R_4(s)$ may be linked to form a substituted or unsubstituted C_5 - C_{30} carbocyclic group or a substituted or unsubstituted C_1 - C_{60} heterocyclic group.

[0098] b_1 to b_4 and b_{11} in Formula 1 may each independently be selected from 1 to 6, wherein, when b_1 is two or more, two or more $R_1(s)$ may be identical to or different from each other, when b_2 is two or more, two or more $R_2(s)$ may be identical to or different from each other, when b_3 is two or more, two or more $R_3(s)$ may be identical to or different from each other, and when b_4 is two or more, two or more $R_4(s)$ may be identical to or different from each other.

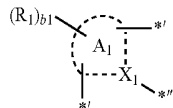
[0099] In Formula 1, a moiety represented by



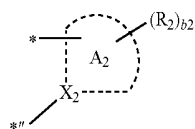
may be identical to a moiety represented by



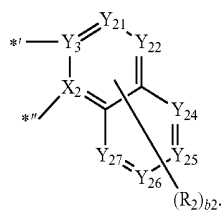
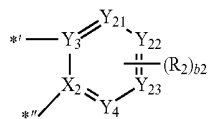
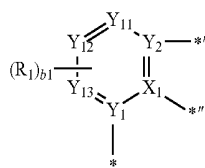
[0100] In Formula 1,



may be represented by Formula 2-1, and



may be represented by Formula 2-2 or Formula 2-3:



[0101] In Formulae 2-1 to 2-3,

[0102] X₁, X₂, R₁, R₂, b₁, and b₂ are the same as described above,

[0103] * and *' respectively indicate binding sites to T₁ and T₂ in Formula 1, and *'' indicates a binding site to M in Formula 1, and

[0104] Y₁ to Y₄, Y₁₁ to Y₁₃, and Y₂₁ to Y₂₇ may each independently be C or N.

[0105] In one embodiment, in Formulae 2-1 to 2-3,

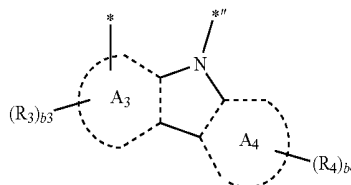
[0106] X₁ and X₂ may each be N, and

[0107] Y₁ to Y₄, Y₁₁ to Y₁₃, and Y₂₁ to Y₂₇ may each be C.

[0108] In Formula 1,

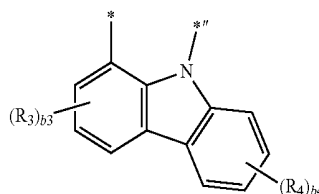
[0109] a moiety represented by

(i)



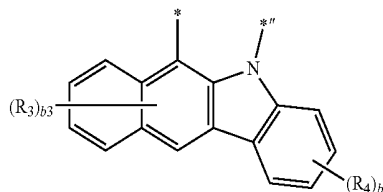
(ii) may be selected from groups represented by Formulae 2-4 to 2-8:

Formula 2-4



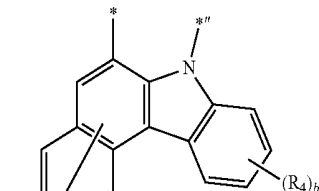
Formula 2-1

Formula 2-5



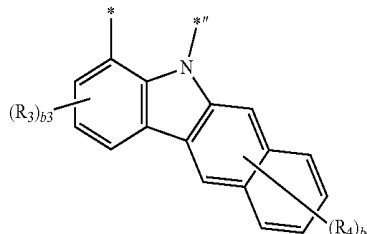
Formula 2-2

Formula 2-6

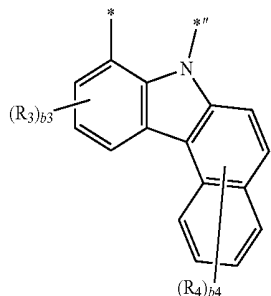


Formula 2-3

Formula 2-7



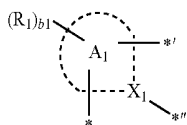
Formula 2-8



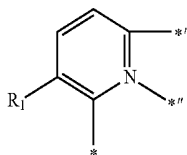
[0110] In Formulae 2-4 to 2-8, * indicates a binding site to T₁ in Formula 1, and ** indicates a binding site to M in Formula 1, and

[0111] R₃, R₄, b₃, and b₄ are the same as described above.

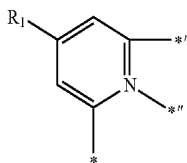
[0112] In Formula 1,



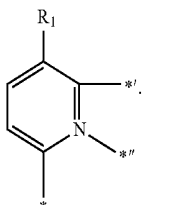
may be selected from groups represented by Formulae 2-1(1) to 2-1(3):



Formula 2-1(1)



Formula 2-1(2)



Formula 2-1(3)

[0113] In Formulae 2-1(1) to 2-1(3), * indicates a binding site to T₁ in Formula 1, ** indicates a binding site to T₂ in Formula 1, and *** indicates a binding site to M in Formula 1, and

[0114] R₁ and b₁ are the same as described above.

[0115] In one embodiment, R₁ in Formulae 2-1(1) to 2-1(3) may be selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₂-C₂₀ alkenyl group, a C₂-C₂₀ alkynyl group, a C₁-C₂₀ alkoxy group, and groups represented by Formulae 5-1 to 5-16.

[0116] L₁ in Formula 1 may be a monovalent organic ligand. The term “monovalent organic ligand” as used herein refers to a ligand having one binding site to a center metal in an organic compound.

[0117] In one embodiment, L₁ may be selected from groups represented by Formulae 3L-1 to 3L-4, but embodiments of the present disclosure are not limited thereto:



[0118] In Formulae 3L-1 to 3L-4,

[0119] Z₁₁ and Z₁₂ may each independently be selected from:

[0120] a benzene group, a naphthalene group, an anthracene group, a phenanthrene group, a phenalene group, a tetracene group, a chrysene group, a pyrene group, a fluoranthene group, a triphenylene group, a fluorene group, and a benzofluorene group; and

[0121] a benzene group, a naphthalene group, an anthracene group, a phenanthrene group, a phenalene group, a tetracene group, a chrysene group, a pyrene group, a fluoranthene group, a triphenylene group, a fluorene group, and a benzofluorene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, and a C₁-C₂₀ alkoxy group,

[0122] c₁₁ and c₁₂ may each independently be selected from 0 to 3, wherein, when c₁₁ is zero, *(Z₁₁)_{c11}* may be a single bond, and when c₁₂ is zero, *(Z₁₂)_{c12}* may be a single bond,

[0123] L₁₂ to L₁₄ are the same as described in connection with L₁₁,

[0124] a₁₂ to a₁₄ are the same as described in connection with a₁₁,

[0125] Ar₁₁ to Ar₁₄ may each independently be selected from 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 C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group,

[0126] X₁₁ may be selected from —F, —Cl, —Br, and —I,

[0127] * indicates a binding site to M in Formula 1,

[0128] at least one substituent of the substituted C₃-C₁₀ cycloalkyl group, the substituted C₁-C₁₀ heterocycloalkyl group, the substituted C₃-C₁₀ cycloalkenyl group, the substituted C₁-C₁₀ heterocycloalkenyl group, the substituted C₆-C₆₀ aryl group, the substituted C₆-C₆₀ aryloxy group, the substituted C₆-C₆₀ arylthio group, the substituted C₁-C₆₀ heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from:

[0129] deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino

group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group;

[0130] 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, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono 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, —Si(Q₁₁)(Q₁₂)(Q₁₃), —N(Q₁₁)(Q₁₂), —B(Q₁₁)(Q₁₂), —C(=O)(Q₁₁), —S(=O)₂(Q₁₁), and —P(=O)(Q₁₁)(Q₁₂);

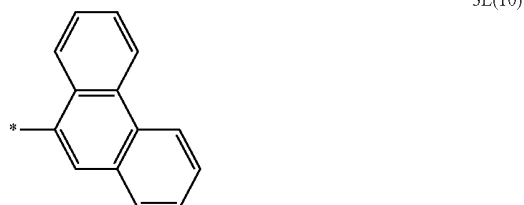
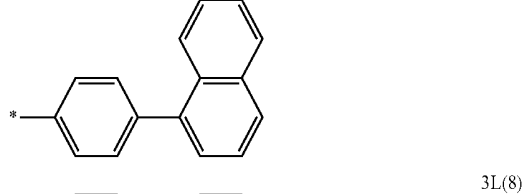
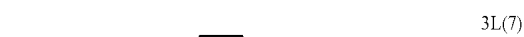
[0131] a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group;

[0132] 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, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, 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, —Si(Q₂₁)(Q₂₂)(Q₂₃), —N(Q₂₁)(Q₂₂), —B(Q₂₁)(Q₂₂), —C(=O)(Q₂₁), —S(=O)₂(Q₂₁), and —P(=O)(Q₂₁)(Q₂₂); and

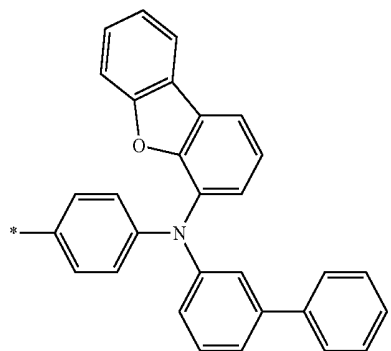
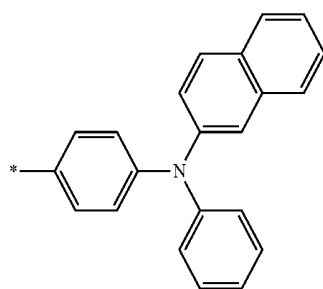
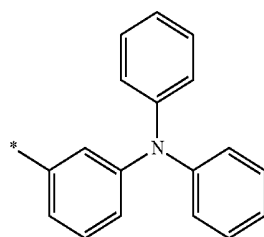
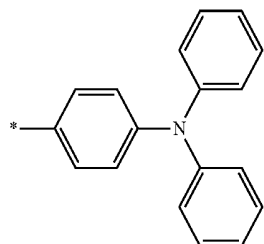
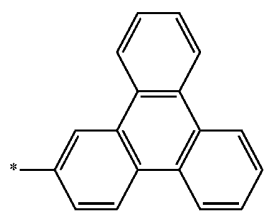
[0133] —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂), and

[0134] Q₁₁ to Q₁₃, Q₂₁ to Q₂₃, and Q₃₁ to Q₃₃ may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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 C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

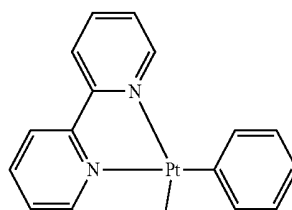
[0135] For example, L₁ in Formula 1 may be selected from groups represented by Formulae 3L(1) to 3L(15):



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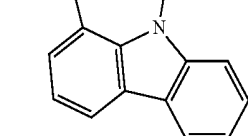


3L(11)



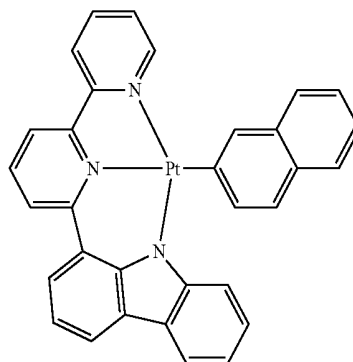
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3L(12)

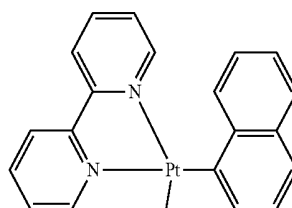


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3L(13)

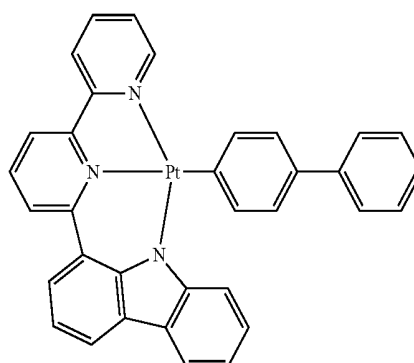


3L(14)



3

3L(15)

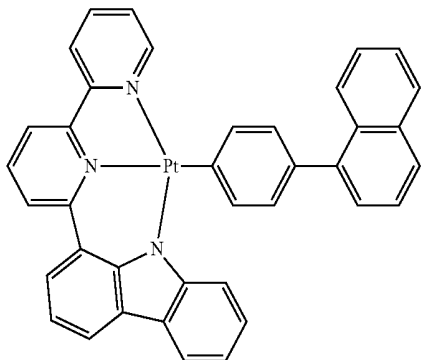


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[0136] The organometallic compound represented by Formula 1 may be one of Compounds 1 to 76, but embodiments of the present disclosure are not limited thereto:

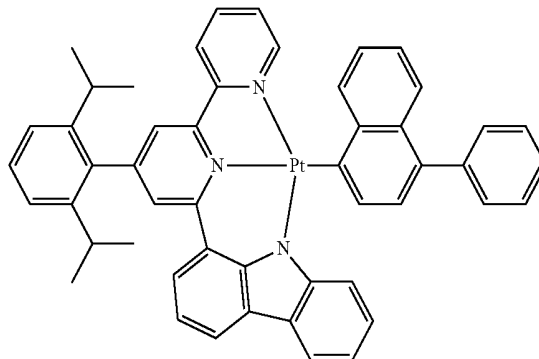
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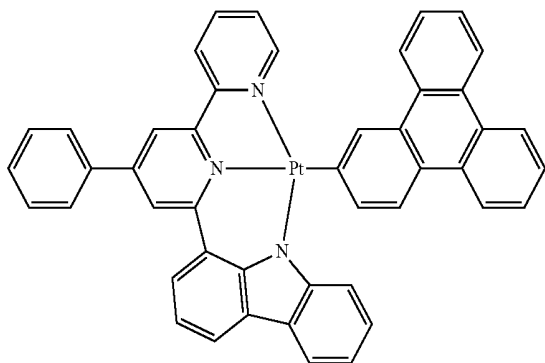


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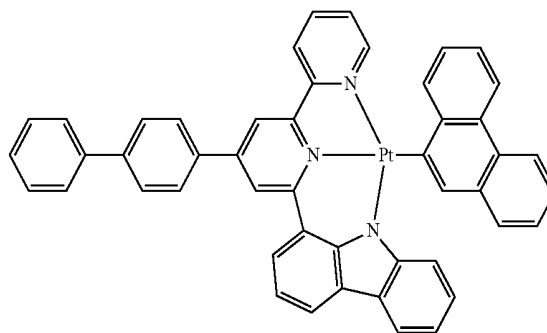
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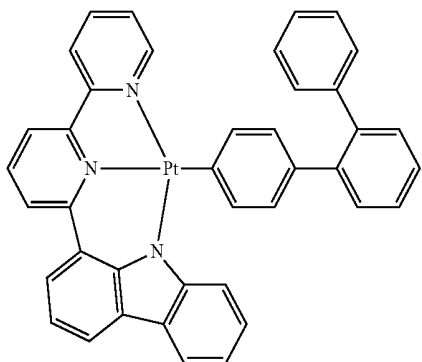
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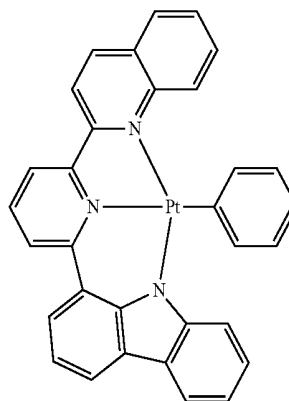
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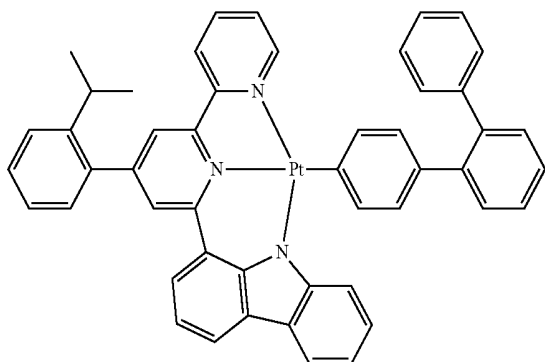
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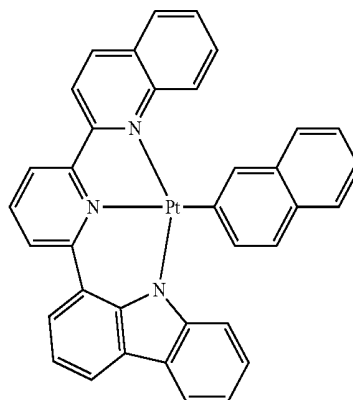
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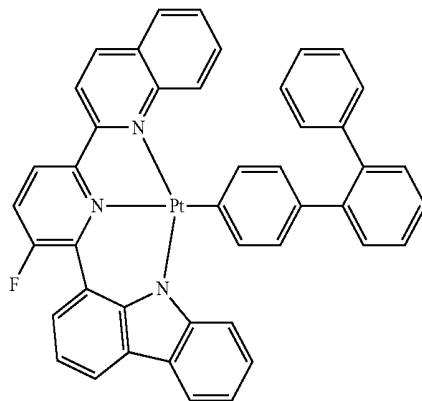
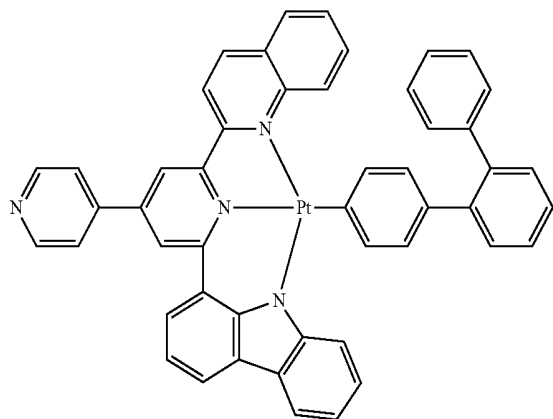
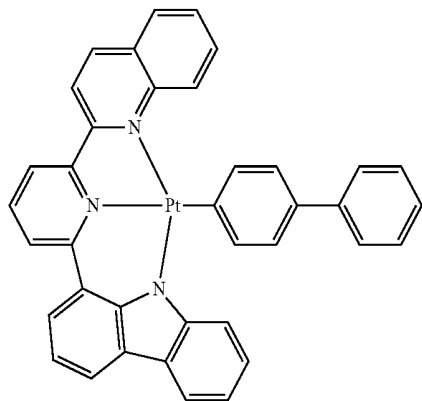
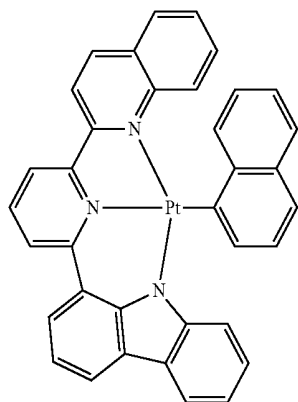
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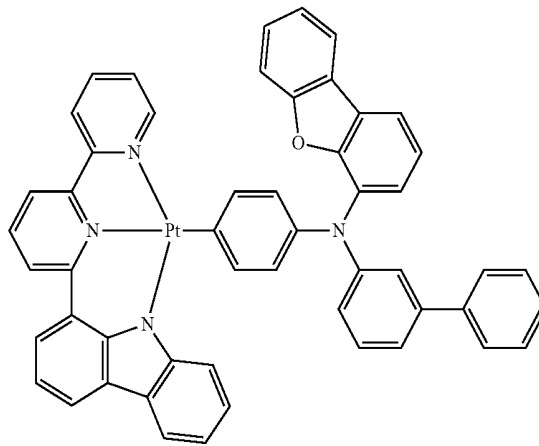
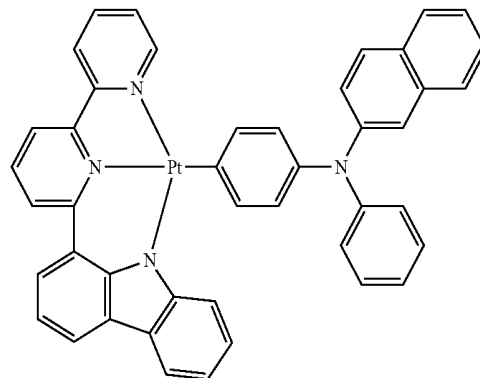
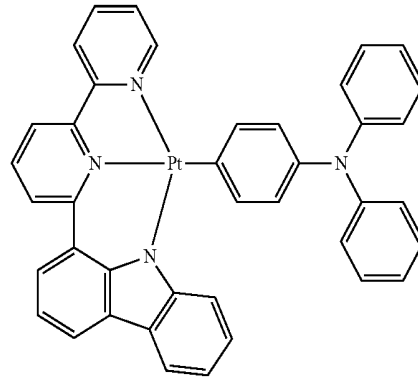
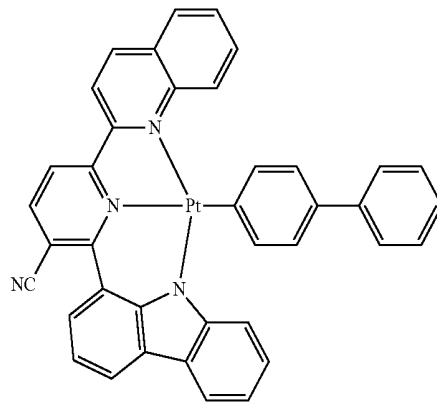
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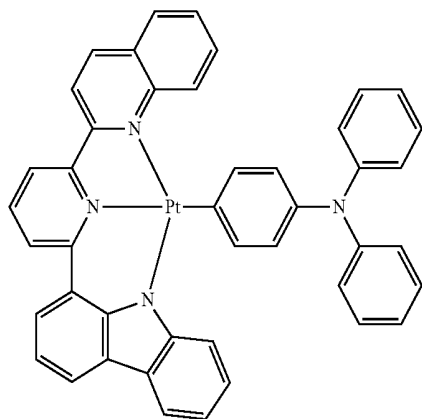
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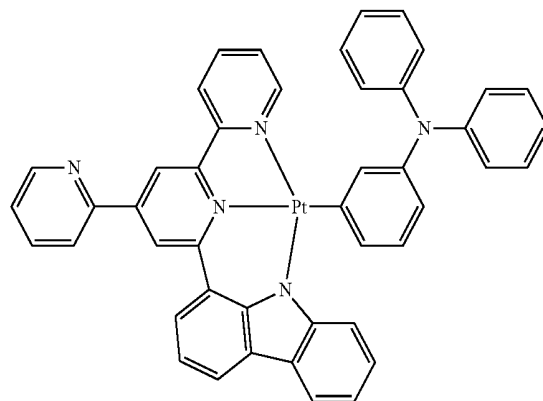
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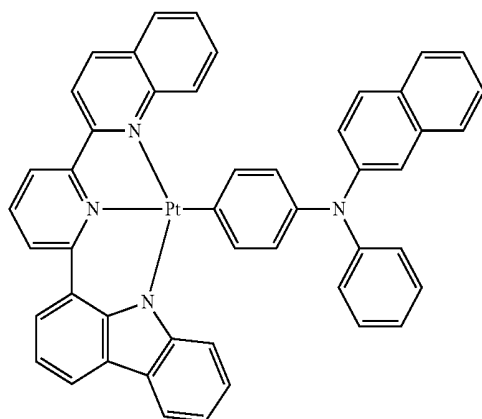


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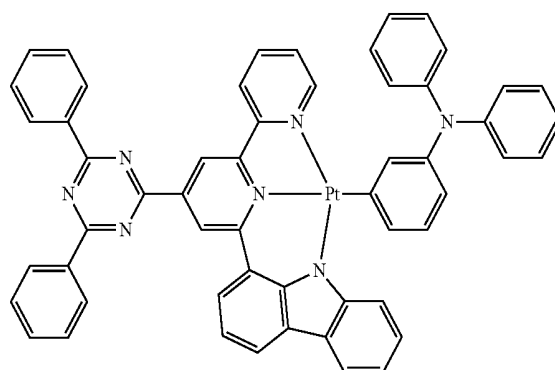
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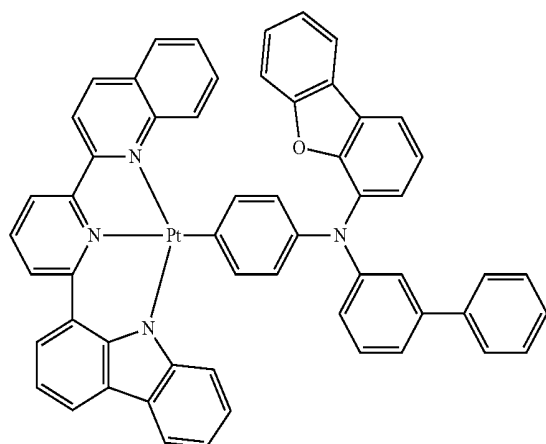
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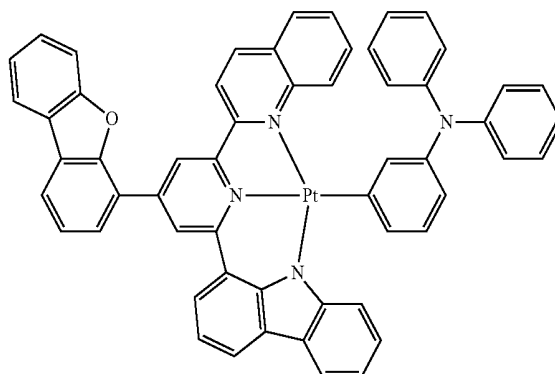
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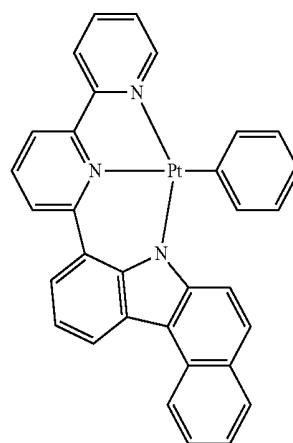
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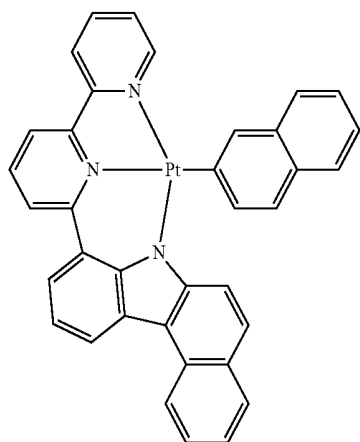


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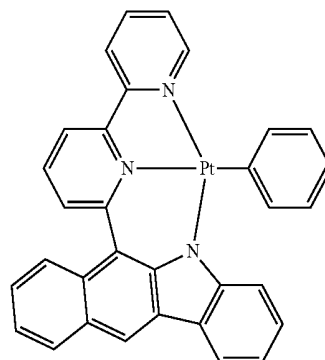
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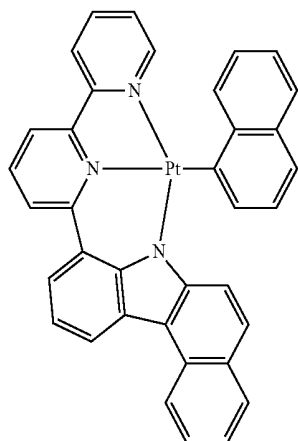


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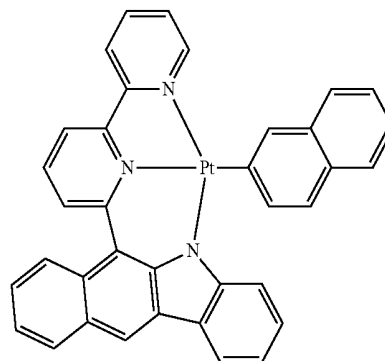
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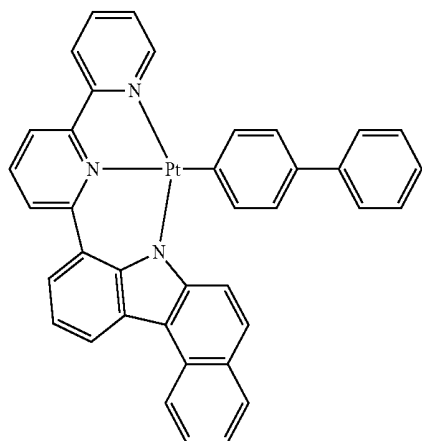
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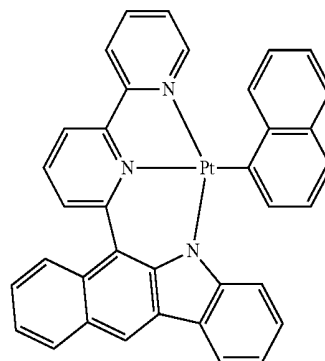
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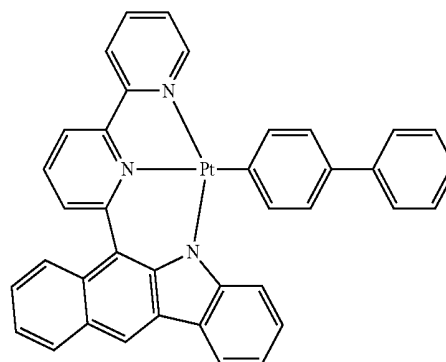
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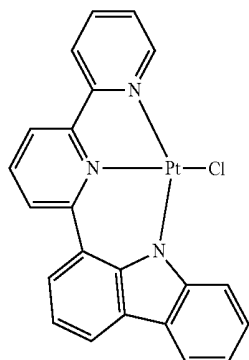


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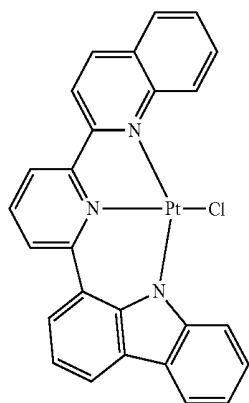


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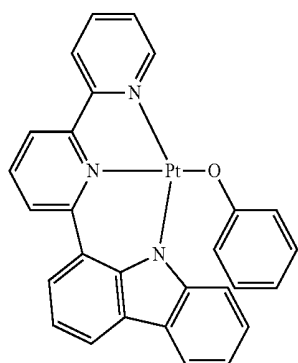
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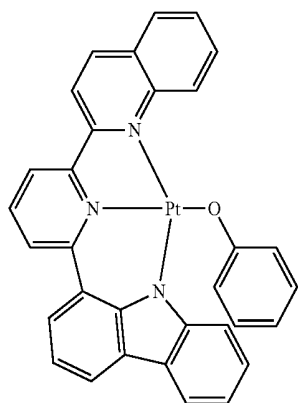
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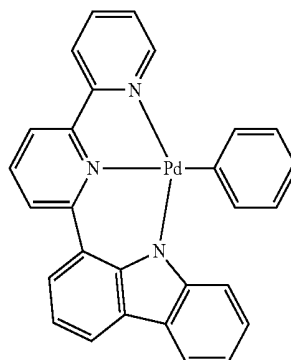


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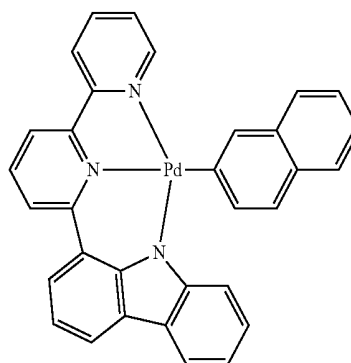


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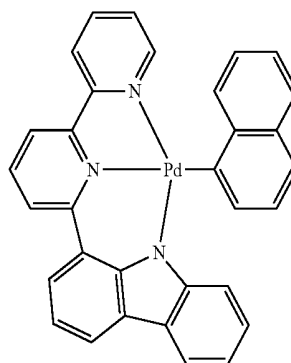
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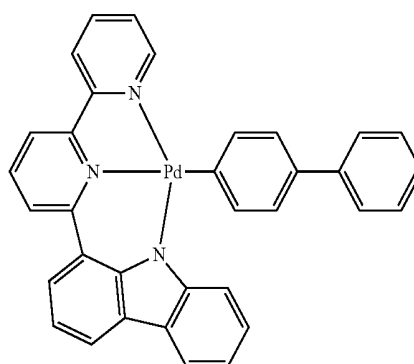
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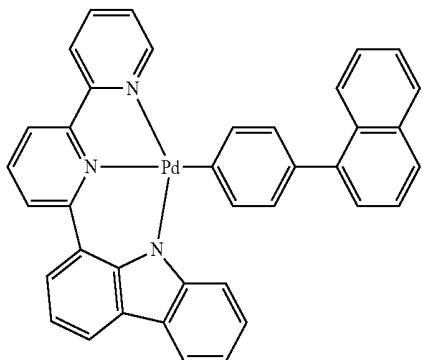
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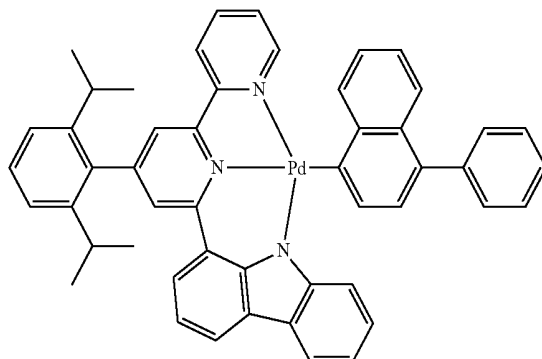
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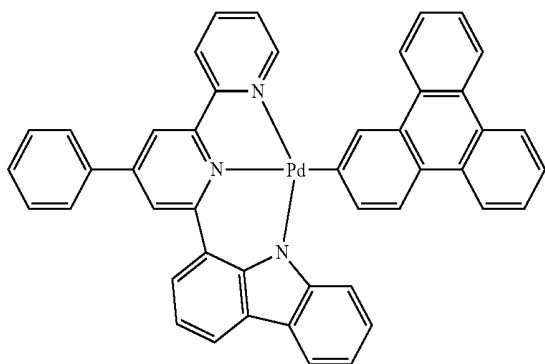


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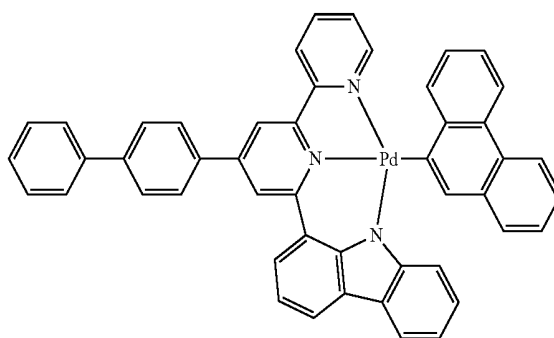
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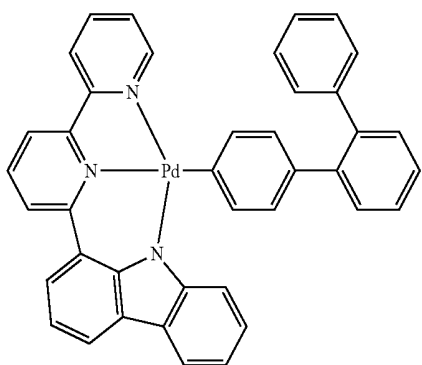
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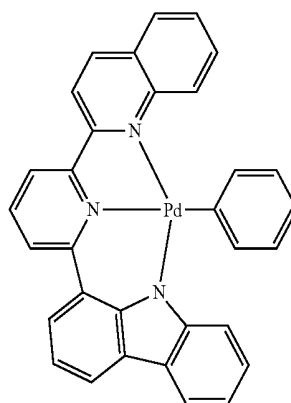
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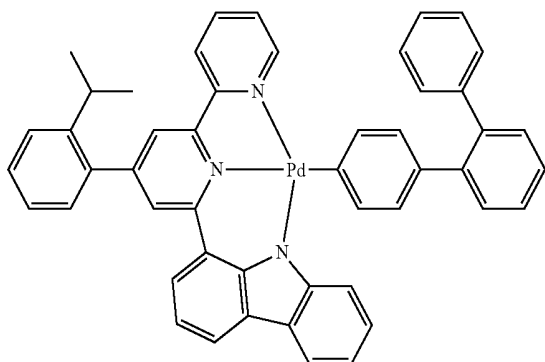
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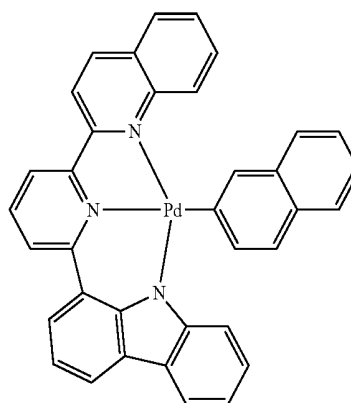
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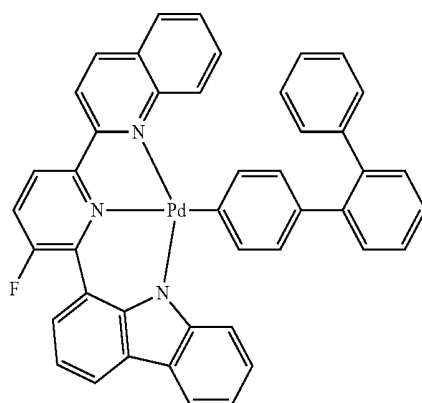
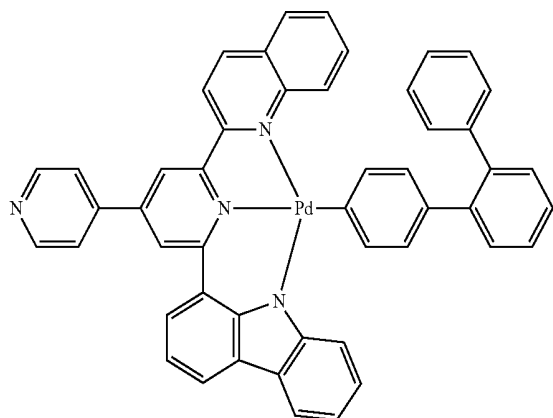
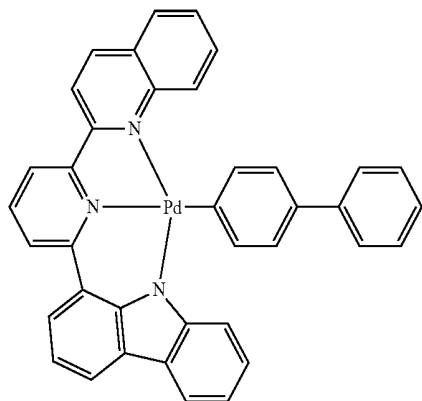
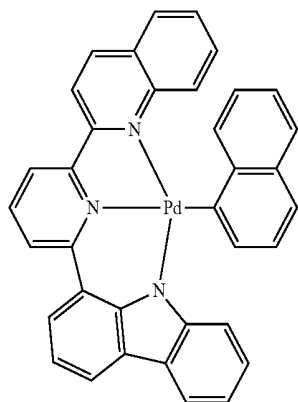
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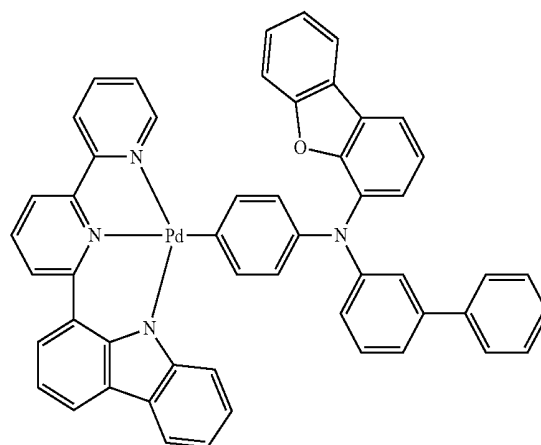
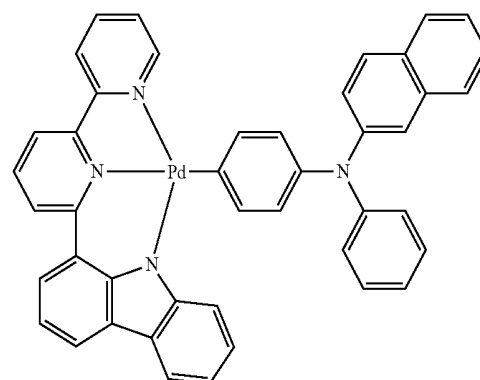
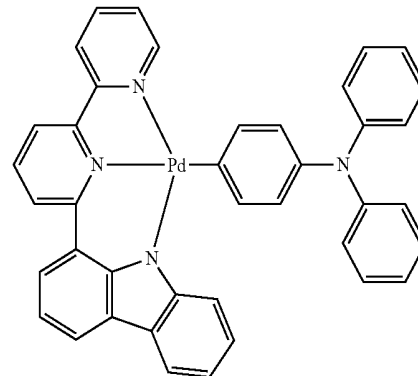
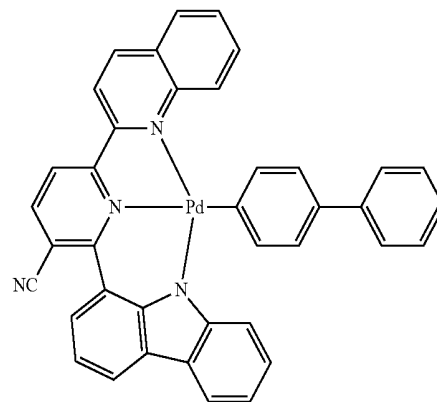
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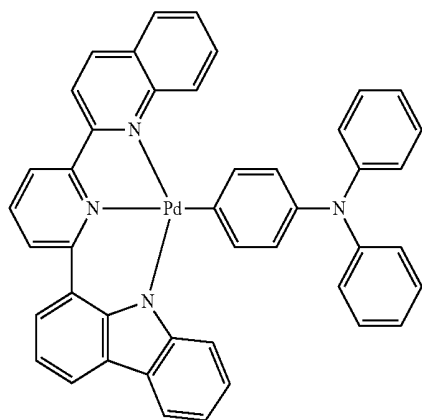
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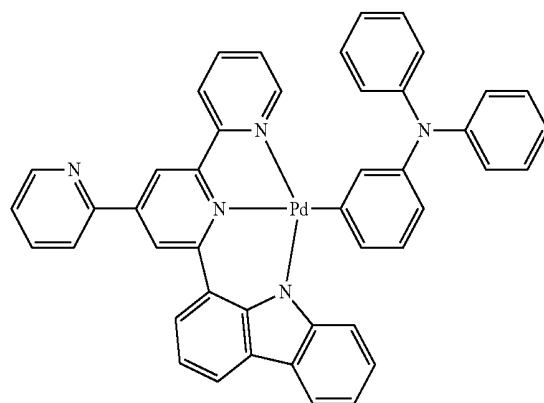
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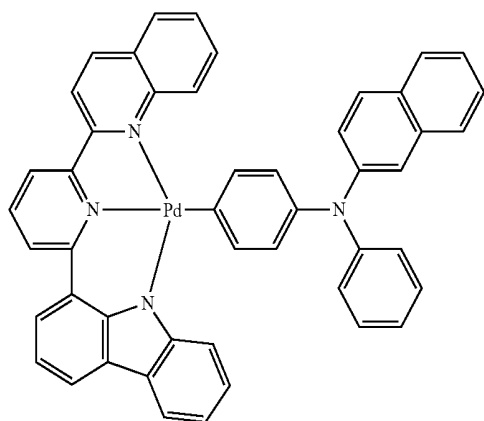


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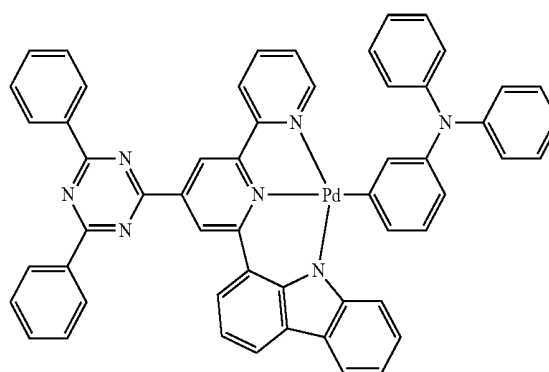
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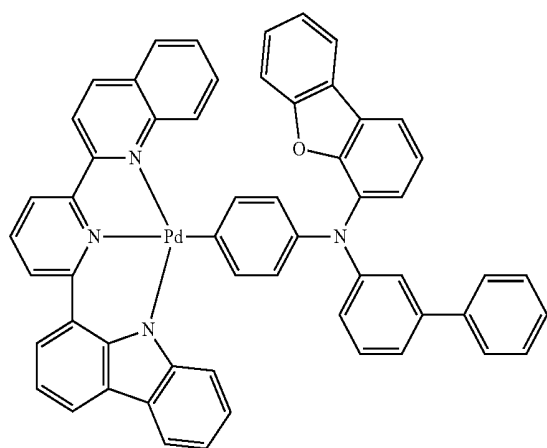
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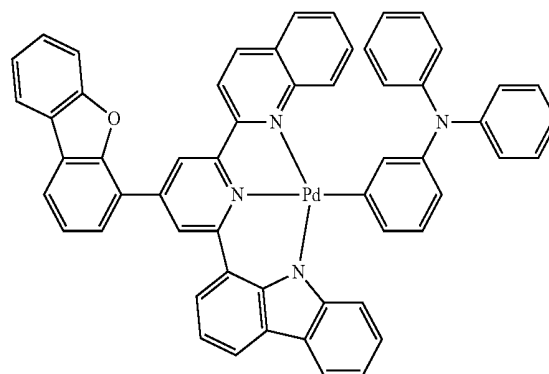
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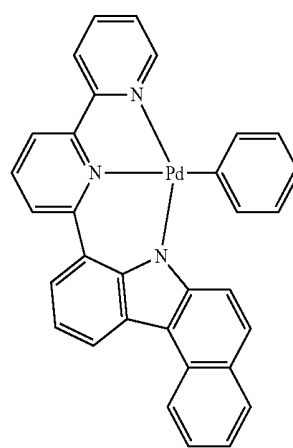
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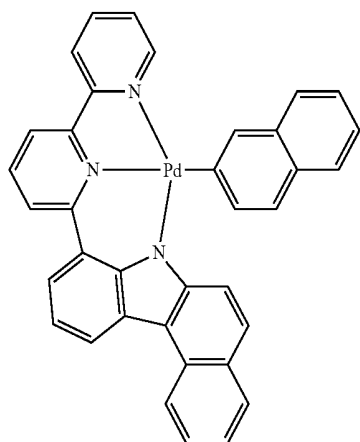


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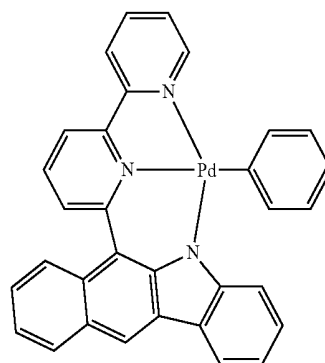
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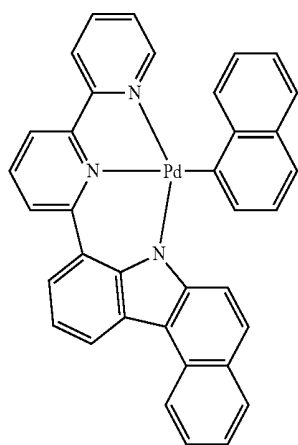


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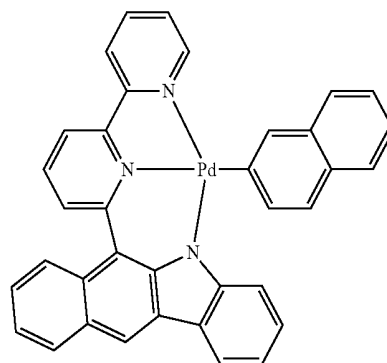
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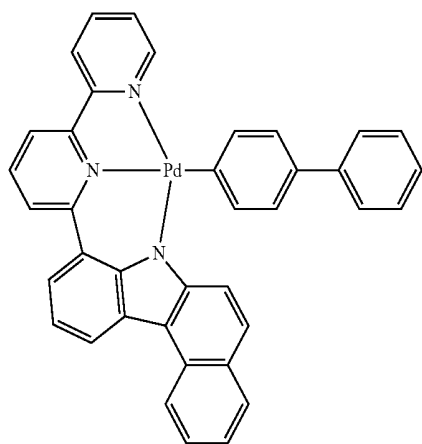
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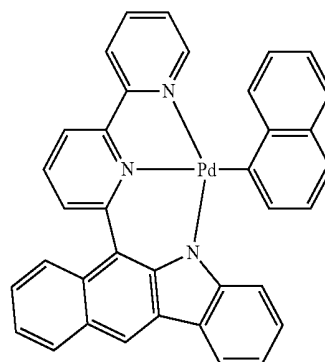
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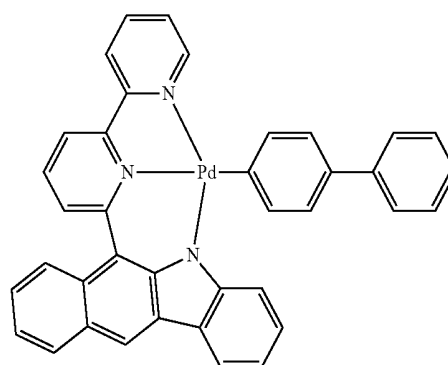
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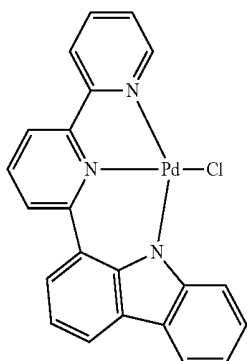


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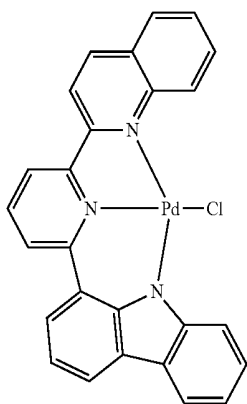
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ligand includes at least one electron donating group moiety, highest occupied molecular orbital (HOMO) of the organometallic compound may be further increased due to a strong electron donation, thus securing a material (e.g., with an emission wavelength) shifted to a near-infrared (NIR) region by a long wavelength.

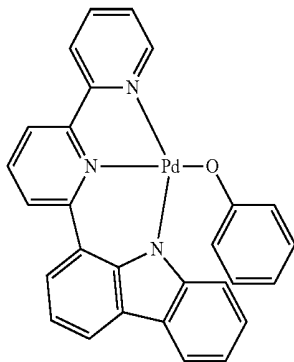
[0138] For example, because the organometallic compound represented by Formula 1 includes a carbazole group in a tridentate ligand, the long wavelength shift effect is excellent, thereby facilitating the design of a material having a desired wavelength, as compared with the case in which the organometallic compound has a phenyl group (e.g., in place of the carbazole group).



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[0139] A synthesis method for the organometallic compound represented by Formula 1 would be apparent to those of ordinary skill in the art by referring to the following examples.

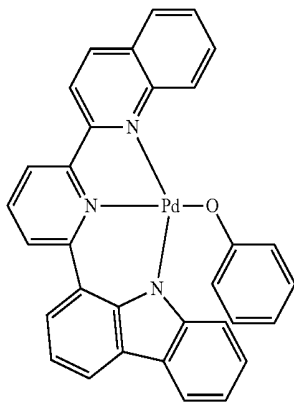
[0140] At least one of the organometallic compounds of Formula 1 may be utilized between a pair of electrodes of an organic light-emitting device. For example, the organometallic compound may be included in an emission layer. In one or more embodiments, the organometallic compound of Formula 1 may be utilized as a material for a capping layer located outside of a pair of electrodes of an organic light-emitting device.



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[0141] Accordingly, an organic light-emitting device is provided to include: a first electrode; a second electrode facing the first electrode; and an organic layer between the first electrode and the second electrode, the organic layer including an emission layer, wherein the organic layer includes at least one organometallic compound.

[0142] The expression “(an organic layer) includes at least one organometallic compound” as used herein may include a case in which “(an organic layer) includes identical compounds represented by Formula 1” and a case in which “(an organic layer) includes two or more different organometallic compounds.”



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[0143] In one embodiment, the first electrode is an anode, and the second electrode is a cathode, and the organic layer further includes a hole transport region between the first electrode and the emission layer and an electron transport region between the emission layer and the second electrode, and the hole transport region includes a hole injection layer, a hole transport layer, an emission auxiliary layer, an electron blocking layer, or any combination thereof, and the electron transport region includes a buffer layer, a hole blocking layer, an electron control layer, an electron transport layer, an electron injection layer, or any combination thereof.

[0144] In one or more embodiments, the emission layer may include the organometallic compound represented by Formula 1.

[0145] In one embodiment, the organometallic compound may have a maximum emission wavelength in a range of about 700 nm to about 1,100 nm. For example, the emission layer including at least one of the organometallic compound may have a maximum emission wavelength in a range of about 700 nm to about 1,100 nm.

[0146] In one embodiment, the emission layer may further include a host, and an amount of the host may be greater than that of the organometallic compound.

[0147] The hole transport region may include a p-dopant, and the p-dopant may include a cyano group-containing compound described below.

[0137] The organometallic compound represented by Formula 1 has a structure in which a transition metal (e.g., Pd or Pt) capable of forming a four-coordinate structure is included as a center metal and the center metal is linked to a tridentate ligand and a monodentate ligand. Because the

[0148] In the organic light-emitting device, the emission layer may be a first color light emission layer, wherein

[0149] the organic light-emitting device may further include i) at least one second color light emission layer or ii) at least one second color light emission layer and at least one third color light emission layer, between the first electrode and the second electrode,

[0150] a maximum emission wavelength of the first color light, a maximum emission wavelength of the second color light, and a maximum emission wavelength of the third color light may be identical to or different from each other, and

[0151] the first color light and the second color light may be emitted in the form of mixed light, or the first color light, the second color light, and the third color light may be emitted in the form of mixed light.

[0152] The organic light-emitting device may further include at least one selected from a first capping layer disposed in a pathway along which light generated in an emission layer proceeds toward the outside through the first electrode and a second capping layer disposed in a pathway along which light generated in an emission layer proceeds toward the outside through the second electrode, and at least one selected from the first capping layer and the second capping layer may include at least one organometallic compound represented by Formula 1.

[0153] For example, the organic light-emitting device may have i) a stacked structure including a first electrode, an organic layer, a second electrode, and a second capping layer which are sequentially stacked in this stated order, ii) a stacked structure including a first capping layer, a first electrode, an organic layer, and a second electrode which are sequentially stacked in this stated order, or iii) a stacked structure including a first capping layer, a first electrode, an organic layer, a second electrode, and a second capping layer which are sequentially stacked in this stated order, and at least one selected from the first capping layer and the second capping layer may include the organometallic compound.

[0154] In one embodiment, there is provided an electronic device including a thin film transistor and the organic light-emitting device, wherein the thin film transistor may include a source electrode, a drain electrode, an activation layer, and a gate electrode, and the first electrode of the organic light-emitting device may be electrically connected with at least one of the source electrode and the drain electrode of the thin film transistor. In one embodiment, there is provided an electronic device including a thin film transistor including a source electrode, a drain electrode, an activation layer, and a gate electrode, wherein the first electrode of the organic light-emitting device may be electrically connected with one of the source electrode and the drain electrode of the thin film transistor.

[0155] The term “organic layer” as used herein refers to a single layer and/or a plurality of layers disposed between the first electrode and the second electrode of the organic light-emitting device. A material included in the “organic layer” is not limited to an organic material.

Description of FIG. 1

[0156] FIG. 1 is a schematic view of an organic light-emitting device 10 according to an embodiment. The organic light-emitting device 10 includes a first electrode 110, an organic layer 150, and a second electrode 190.

[0157] Hereinafter, the structure of the organic light-emitting device 10 according to an embodiment and a method of

manufacturing the organic light-emitting device 10 will be described in connection with FIG. 1.

First Electrode 110

[0158] In FIG. 1, a substrate may be additionally disposed under the first electrode 110 or above the second electrode 190. The substrate may be a glass substrate or a plastic substrate, each having excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and/or water resistance.

[0159] The first electrode 110 may be formed by depositing or sputtering a material for forming the first electrode 110 on the substrate. When the first electrode 110 is an anode, the material for the first electrode may be selected from materials with a high work function to facilitate hole injection.

[0160] The first electrode 110 may be a reflective electrode, a semi-transmissive electrode, or a transmissive electrode. When the first electrode 110 is a transmissive electrode, a material for forming the first electrode may be selected from indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO₂), zinc oxide (ZnO), and any combinations thereof, but embodiments of the present disclosure are not limited thereto. In one or more embodiments, when the first electrode 110 is a semi-transmissive electrode or a reflective electrode, a material for forming the first electrode may be selected from magnesium (Mg), silver (Ag), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), magnesium-silver (Mg—Ag), and any combinations thereof, but embodiments of the present disclosure are not limited thereto.

[0161] The first electrode 110 may have a single-layered structure, or a multi-layered structure including two or more layers. For example, the first electrode 110 may have a three-layered structure of ITO/Ag/ITO, but the structure of the first electrode 110 is not limited thereto.

Organic Layer 150

[0162] The organic layer 150 is disposed on the first electrode 110. The organic layer 150 may include an emission layer.

[0163] The organic layer 150 may further include a hole transport region between the first electrode 110 and the emission layer, and an electron transport region between the emission layer and the second electrode 190.

Hole Transport Region in Organic Layer 150

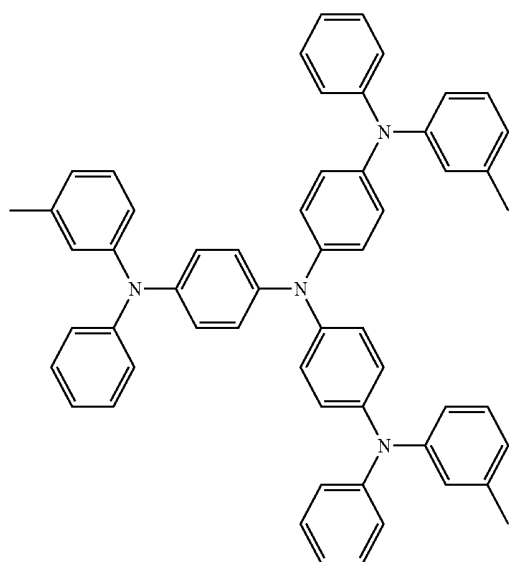
[0164] The hole transport region may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

[0165] The hole transport region may include at least one layer selected from a hole injection layer, a hole transport layer, an emission auxiliary layer, and an electron blocking layer.

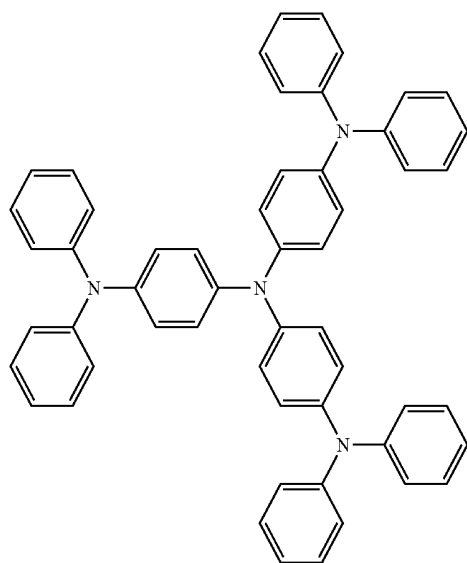
[0166] For example, the hole transport region may have a single-layered structure including a single layer including a plurality of different materials, or a multi-layered structure having a hole injection layer/hole transport layer structure, a hole injection layer/hole transport layer/emission auxiliary layer structure, a hole injection layer/emission auxiliary

layer structure, a hole transport layer/emission auxiliary layer structure, or a hole injection layer/hole transport layer/electron blocking layer structure, wherein for each structure, constituting layers are sequentially stacked from the first electrode 110 in the respective stated order, but the structure of the hole transport region is not limited thereto.

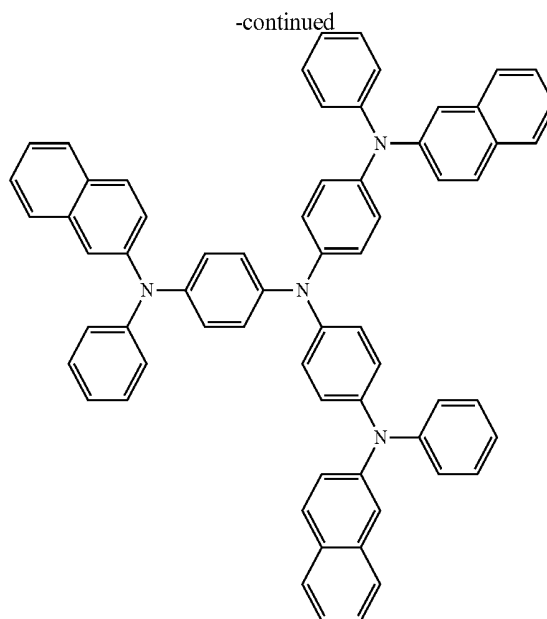
[0167] The hole transport region may include at least one selected from m-MTDATA, TDATA, 2-TNATA, NPB (NPD), β -NPB, TPD, Spiro-TPD, Spiro-NPB, methylated-NPB, TAPC, HMTPD, 4,4',4''-tris(N-carbazolyl)triphenylamine (TCTA), polyaniline/dodecylbenzenesulfonic acid (PANI/DBSA), poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate) (PEDOT/PSS), polyaniline/camphor sulfonic acid (PANI/CSA), polyaniline/poly(4-styrenesulfonate) (PANI/PSS), a compound represented by Formula 201, and a compound represented by Formula 202:



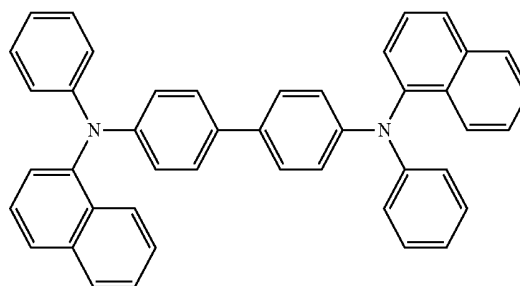
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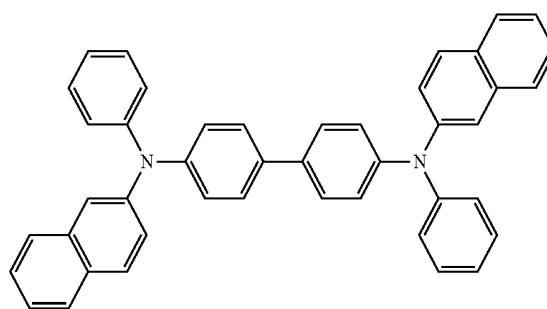
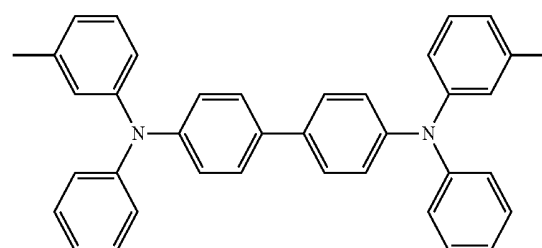
TDATA



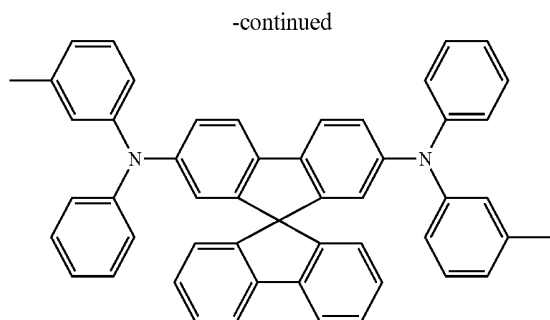
2-TNATA



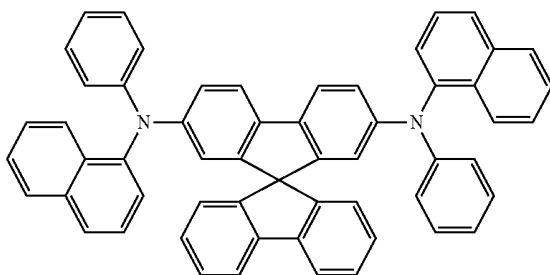
NPB

 β -NPB

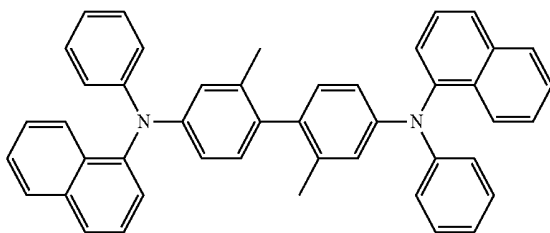
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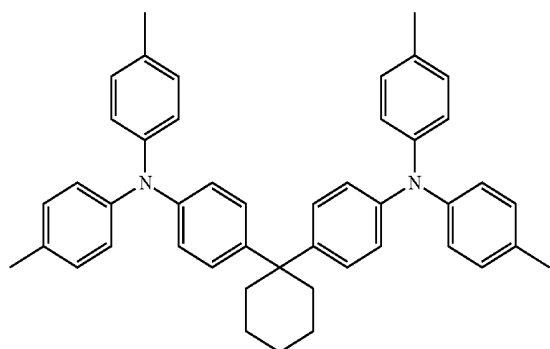
Spiro-TPD



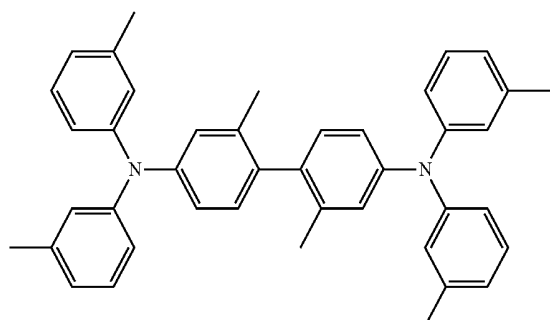
Spiro-NPB



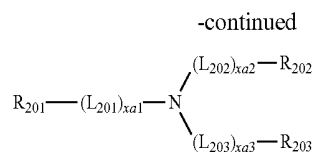
methylated NPB



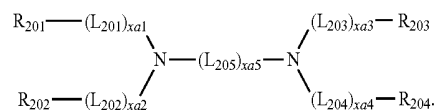
TAPC



HMTPD



Formula 201



Formula 202

[0168] In Formulae 201 and 202,

[0169] L_{201} to L_{204} may each independently be selected from a substituted or unsubstituted C_3 - C_{10} cycloalkylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3 - C_{10} cycloalkenylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6 - C_{60} arylene group, a substituted or unsubstituted C_1 - C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0170] L_{205} may be selected from $^*-\text{O}-^*$, $^*-\text{S}-^*$, $^*-\text{N}(\text{Q}_{201})-^*$, a substituted or unsubstituted C_1 - C_{20} alkylene group, a substituted or unsubstituted C_2 - C_{20} alkenylene group, a substituted or unsubstituted C_3 - C_{10} cycloalkylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3 - C_{10} cycloalkenylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6 - C_{60} arylene group, a substituted or unsubstituted C_1 - C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0171] $\text{xa}1$ to $\text{xa}4$ may each independently be an integer from 0 to 3,

[0172] $\text{xa}5$ may be an integer from 1 to 10, and

[0173] R_{201} to R_{204} and Q_{201} may each independently be selected from a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6 - C_{60} aryl group, a substituted or unsubstituted C_6 - C_{60} aryloxy group, a substituted or unsubstituted C_6 - C_{60} arylthio group, a substituted or unsubstituted C_1 - C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group.

[0174] For example, in Formula 202, R_{201} and R_{202} may be optionally linked via a single bond, a dimethyl-methylene group, or a diphenyl-methylene group, and R_{203} and R_{204} may optionally be linked via a single bond, a dimethyl-methylene group, or a diphenyl-methylene group.

[0175] In one or more embodiments, in Formulae 201 and 202,

[0176] L_{201} to L_{205} may each independently be selected from:

[0177] a phenylene group, a pentalenylene group, an indenylene group, a naphthalenylene group, an azulenylene group, a

heptalenylenylene group, an indacenylene group, an acenaphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenalenylenylene group, a phenanthrenylene group, an anthracenylenylene group, a fluoranthenylenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylenylene group, a picenylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylenylene group, a pentacenylenylene group, a rubicenylenylene group, a coronenylenylene group, an ovalenylenylene group, a thiophenylenylene group, a furanylenylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylenylene group, a benzothiophenylenylene group, a dibenzofuranylenylene group, a dibenzothiophenylenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, and a pyridinylenylene group; and

[0178] a phenylene group, a pentalenylenylene group, an indenylene group, a naphthylene group, an azulenylenylene group, a heptalenylenylene group, an indacenylene group, an acenaphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenalenylenylene group, a phenanthrenylene group, an anthracenylenylene group, a fluoranthenylenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylenylene group, a picenylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylenylene group, a pentacenylenylene group, a rubicenylenylene group, a coronenylenylene group, an ovalenylenylene group, a thiophenylenylene group, a furanylenylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylenylene group, a benzothiophenylenylene group, a dibenzofuranylenylene group, a dibenzothiophenylenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, and a pyridinylenylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C₁-C₁₀ alkyl group, a phenyl group substituted with —F, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenylenylene group, a pentacenylenylene group, a rubicenylenylene group, a coronenylenylene group, an ovalenylenylene group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), and —N(Q₃₁)(Q₃₂), and

[0179] Q₃₁ to Q₃₃ may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0180] In one or more embodiments, xa1 to xa4 may each independently be 0, 1, or 2.

[0181] In one or more embodiments, xa5 may be 1, 2, 3, or 4.

[0182] In one or more embodiments, R₂₀₁ to R₂₀₄ and Q₂₀₁ may each independently be selected from:

[0183] a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenylenylene group, a pentacenylenylene group, a rubicenylenylene group, a coronenylenylene group, an ovalenylenylene group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group; and

[0184] a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenylenylene group, a pentacenylenylene group, a rubicenylenylene group, a coronenylenylene group, an ovalenylenylene group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C₁-C₁₀ alkyl group, a phenyl group substituted with —F, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenylenylene group, a pentacenylenylene group, a rubicenylenylene group, a coronenylenylene group, an ovalenylenylene group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), and —N(Q₃₁)(Q₃₂), and

[0185] Q₃₁ to Q₃₃ are the same as described above.

[0186] In one or more embodiments, in Formula 201, at least one selected from R₂₀₁ to R₂₀₃ may each independently be selected from:

[0187] a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

[0188] a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C₁-C₁₀ alkyl group, a phenyl group substituted with —F, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, but embodiments of the present disclosure are not limited thereto.

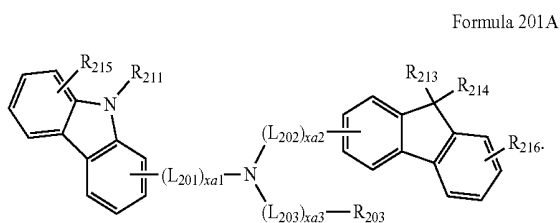
[0189] In one or more embodiments, in Formula 202, i) R₂₀₁ and R₂₀₂ may be linked via a single bond, and/or ii) R₂₀₃ and R₂₀₄ may be linked via a single bond.

[0190] In one or more embodiments, in Formula 202, at least one selected from R₂₀₁ to R₂₀₄ may be selected from:

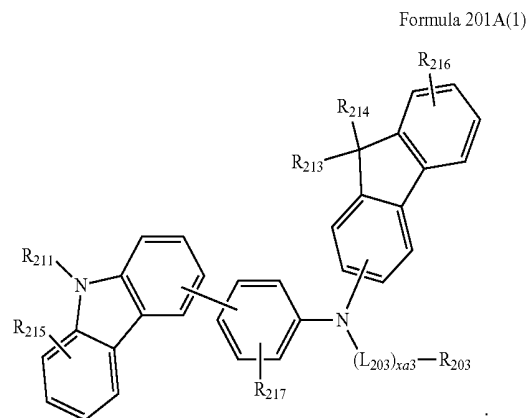
[0191] a carbazolyl group; and

[0192] a carbazolyl group substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C₁-C₁₀ alkyl group, a phenyl group substituted with —F, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, but embodiments of the present disclosure are not limited thereto.

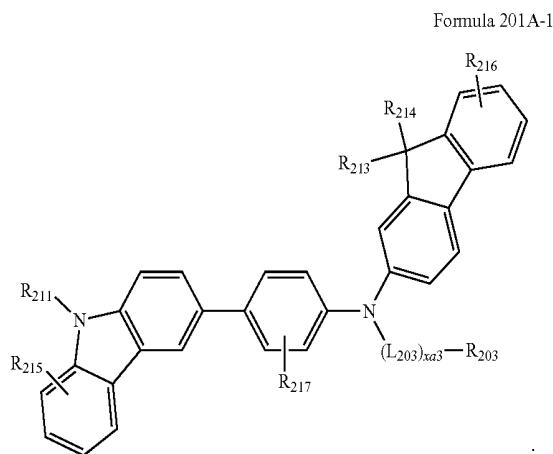
[0193] The compound represented by Formula 201 may be represented by Formula 201A:



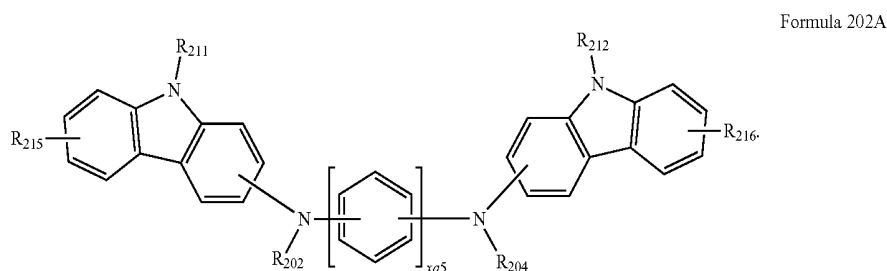
[0194] For example, the compound represented by Formula 201 may be represented by Formula 201A(1), but embodiments of the present disclosure are not limited thereto:



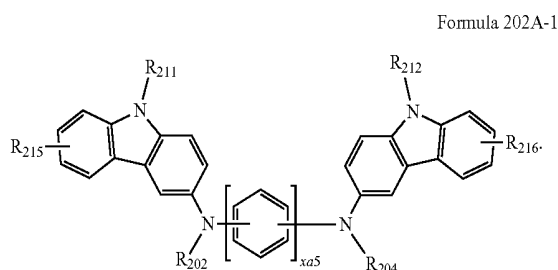
[0195] In one embodiment, the compound represented by Formula 201 may be represented by Formula 201A-1, but embodiments of the present disclosure are not limited thereto:



[0196] In one or more embodiments, the compound represented by Formula 202 may be represented by Formula 202A:



[0197] In one or more embodiments, the compound represented by Formula 202 may be represented by Formula 202A-1:



[0198] In Formulae 201A, 201A(1), 201A-1, 202A, and 202A-1,

[0199] L_{201} to L_{203} , $xa1$ to $xa3$, $xa5$, and R_{202} to R_{204} are the same as described above,

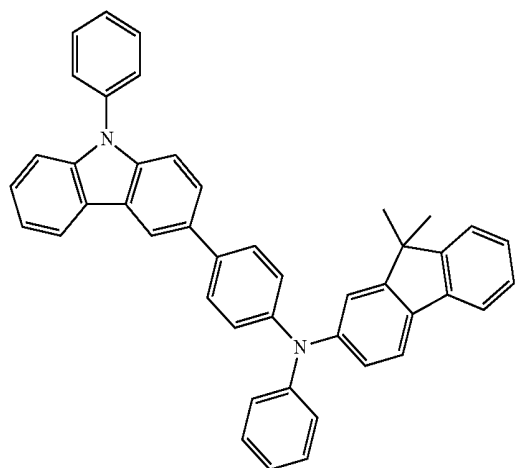
[0200] R_{211} and R_{212} are the same as described in connection with R_{203} , and

[0201] R_{213} to R_{217} may each independently be selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group,

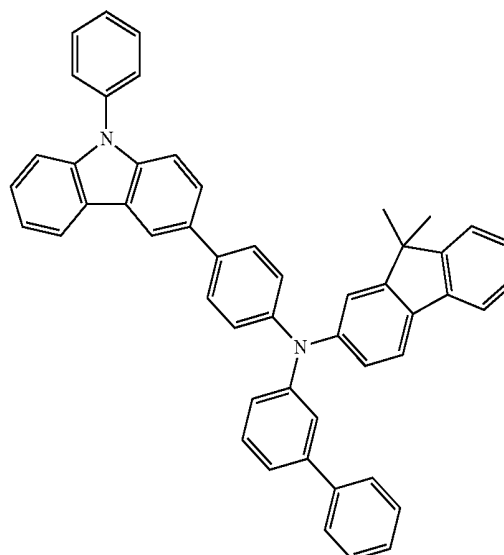
a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1 - C_{10} alkyl group, a phenyl group substituted with $-F$, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group.

[0202] The hole transport region may include at least one compound selected from Compounds HT1 to HT39, but embodiments of the present disclosure are not limited thereto:

HT1

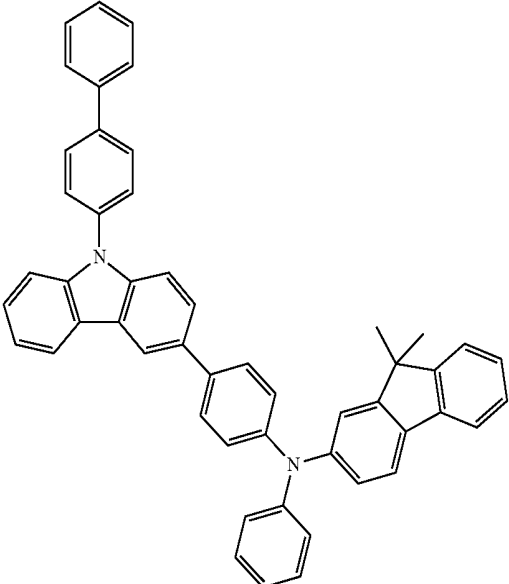
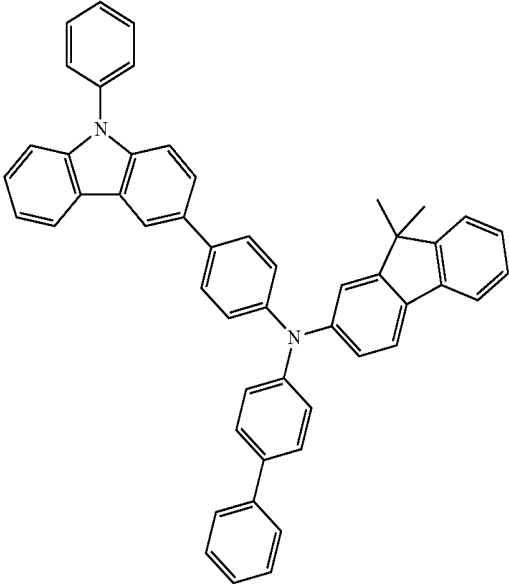


HT2



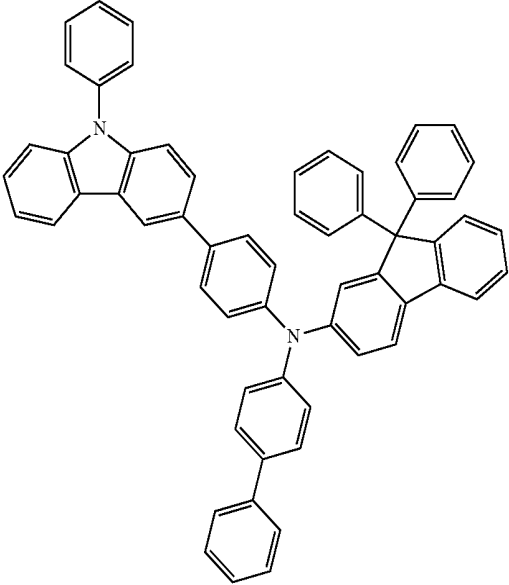
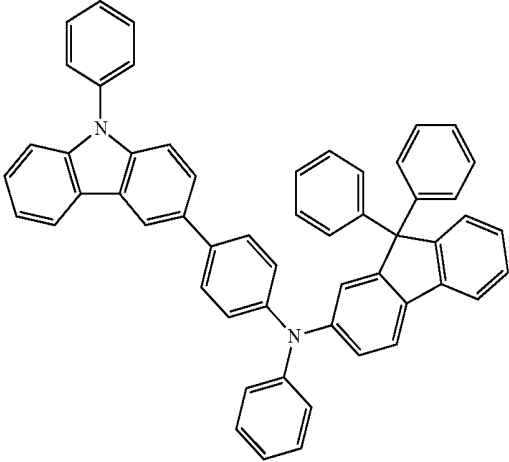
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HT3

HT4



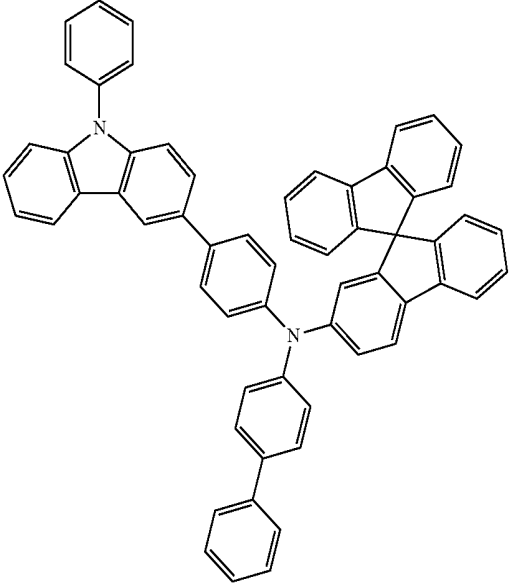
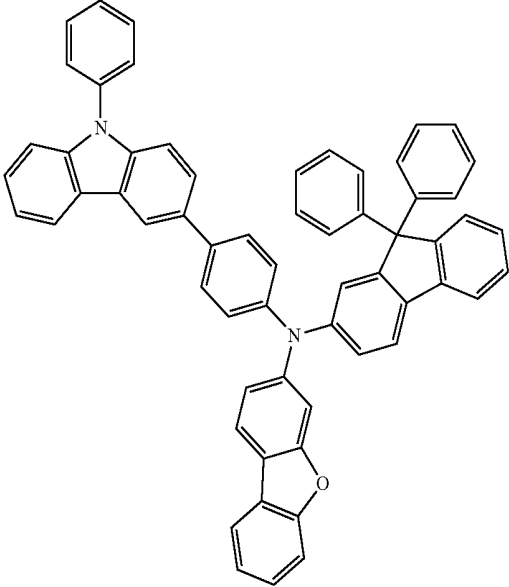
HT5

HT6



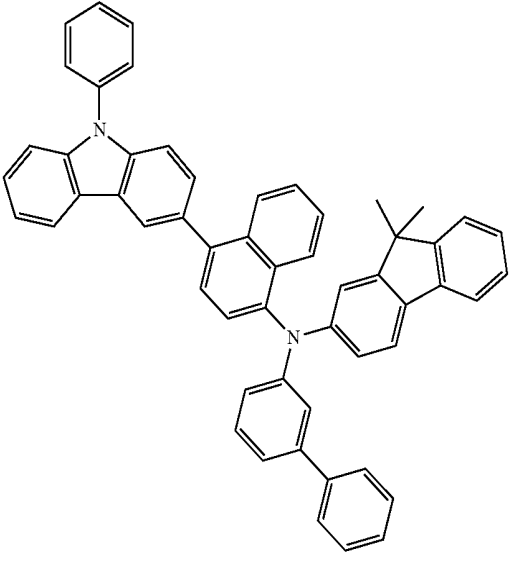
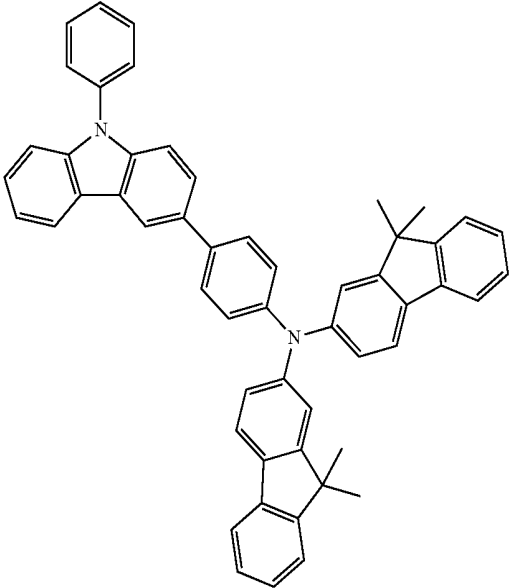
-continued
HT7

HT8



HT9

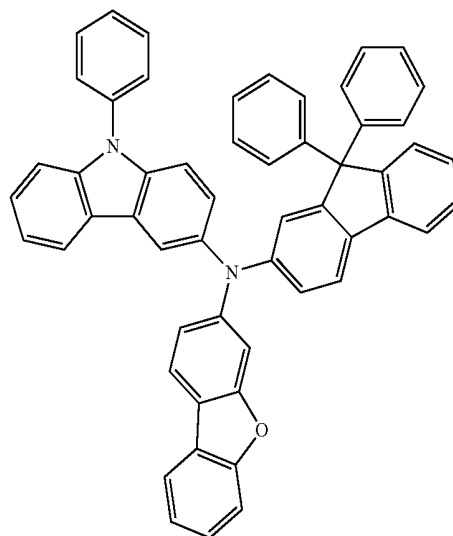
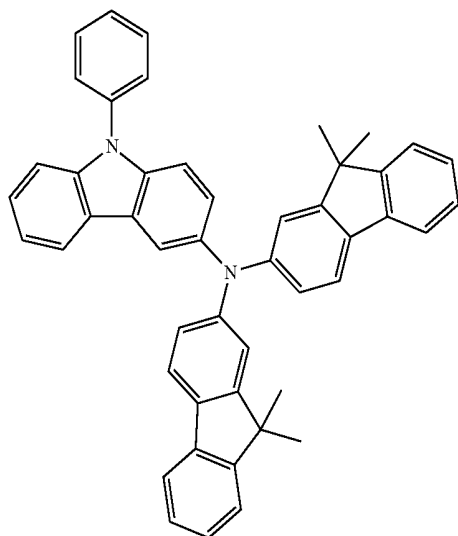
HT10



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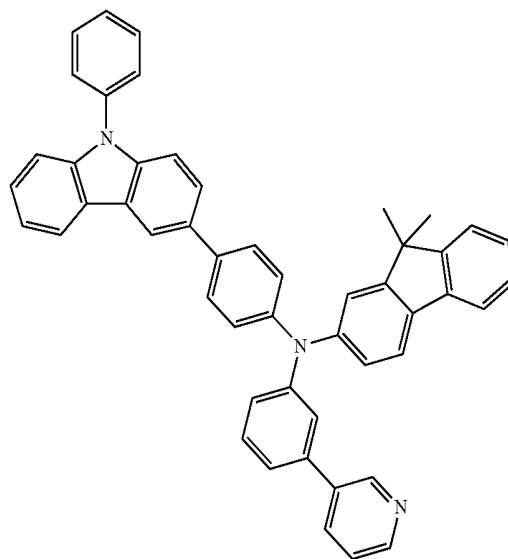
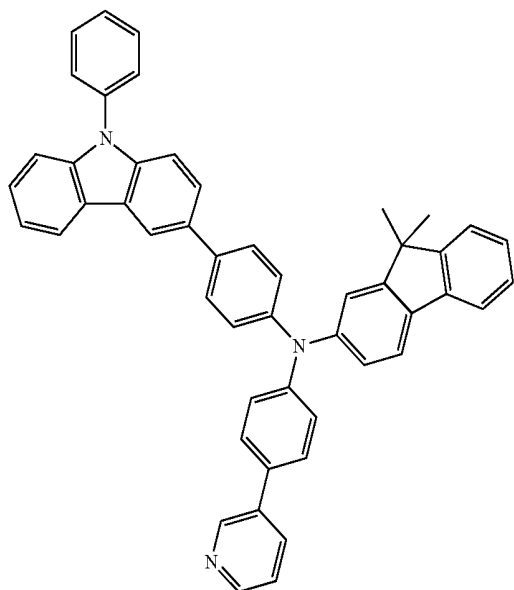
HT11

HT12



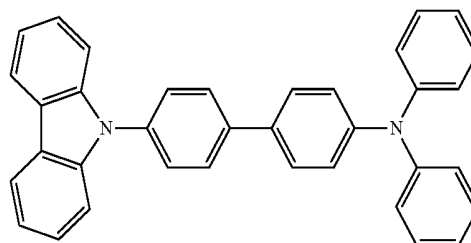
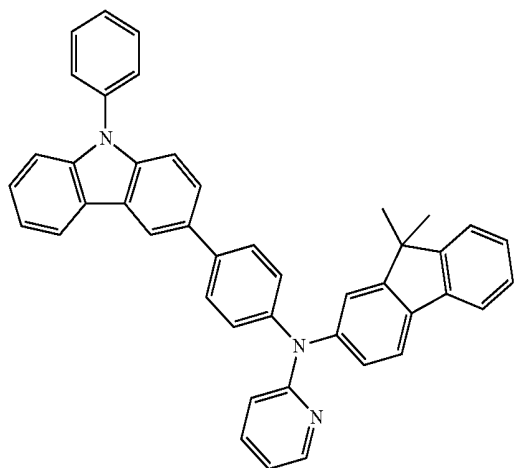
HT13

HT14

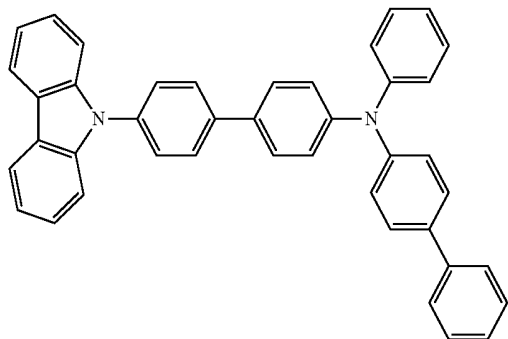


HT15

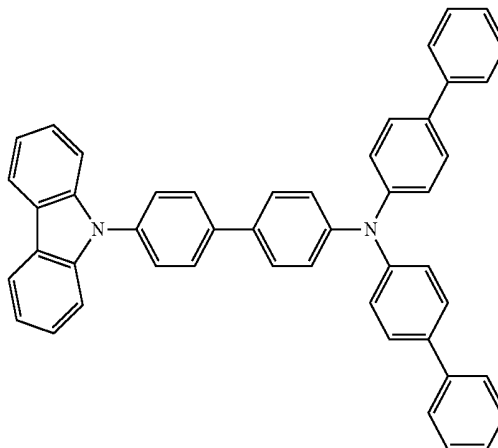
HT16



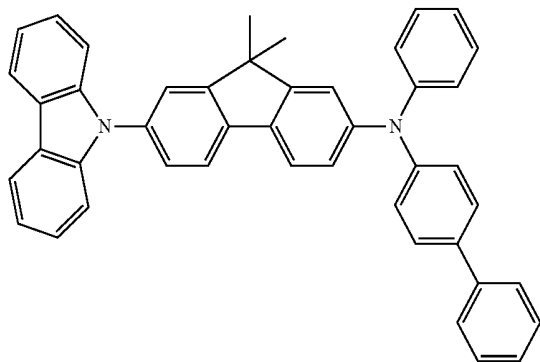
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HT17



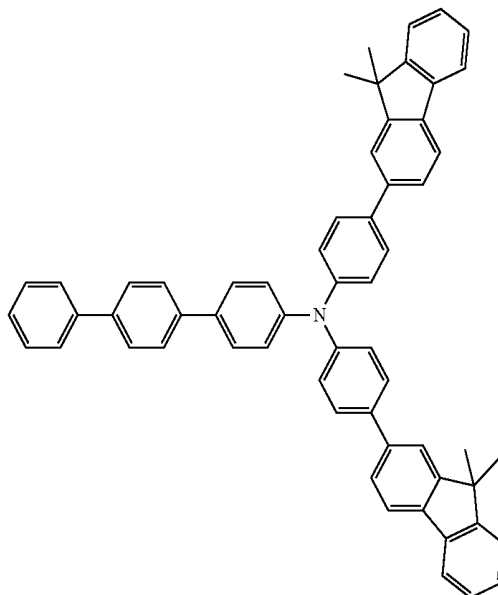
HT18



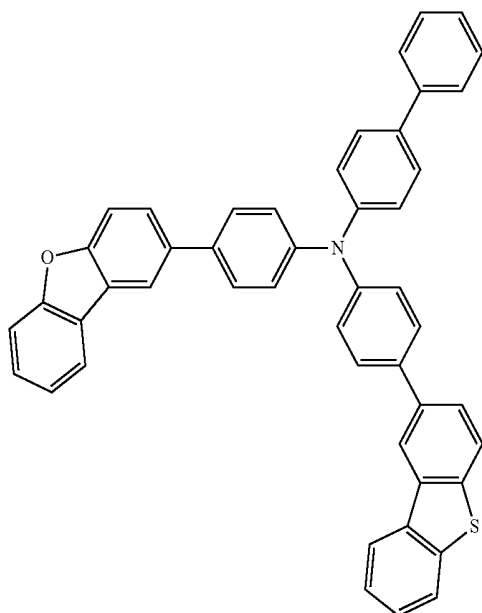
HT19



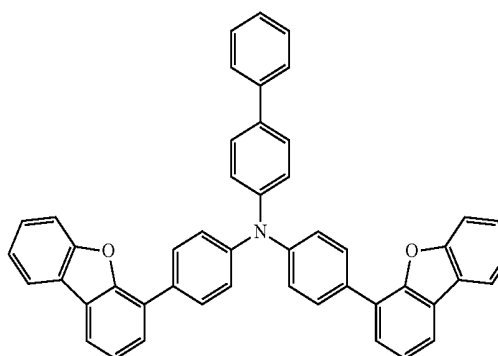
HT20



HT21

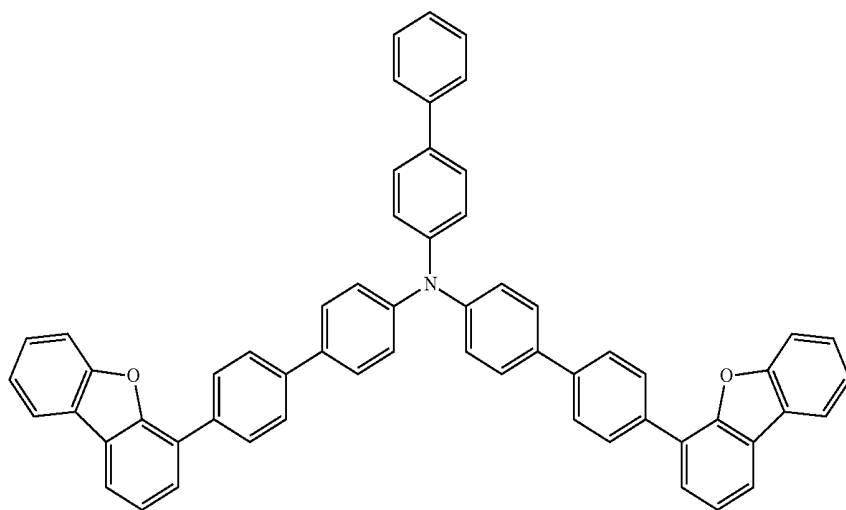


HT22



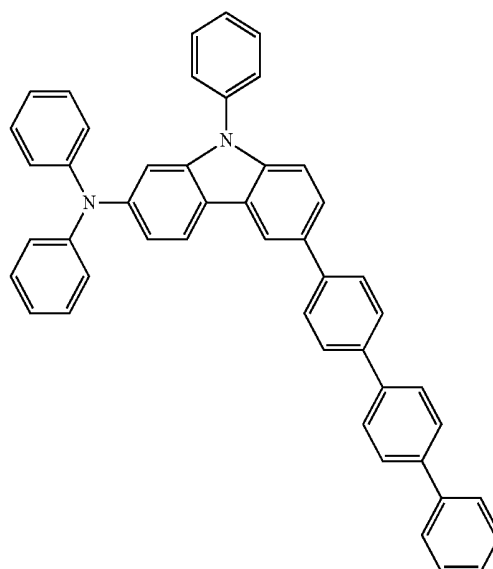
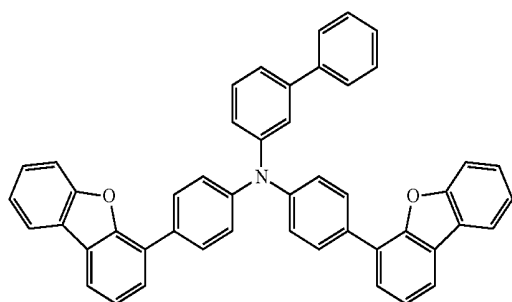
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HT23



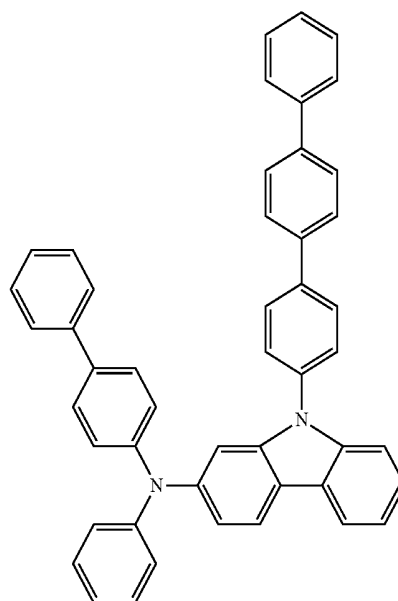
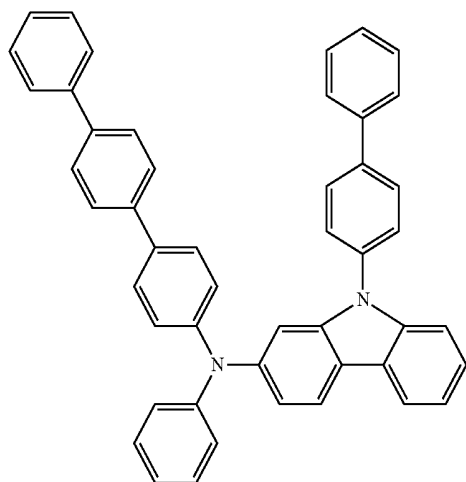
HT24

HT25

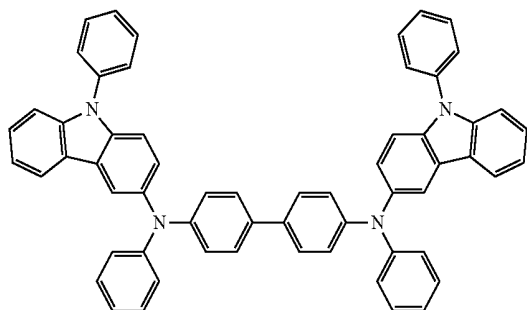


HT26

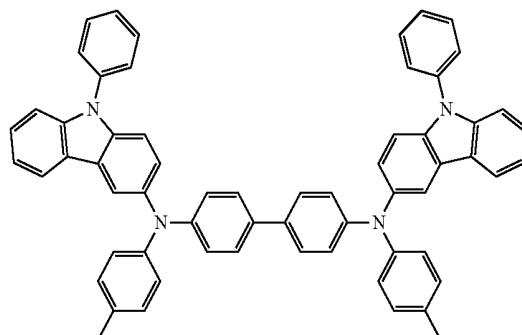
HT27



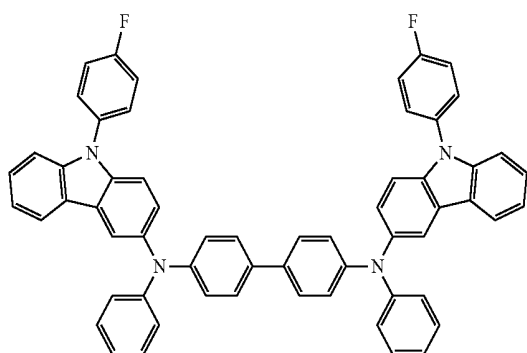
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HT28



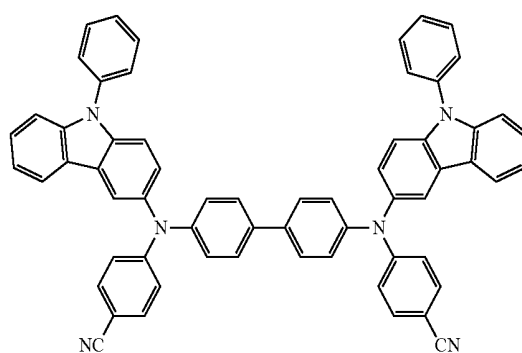
HT29



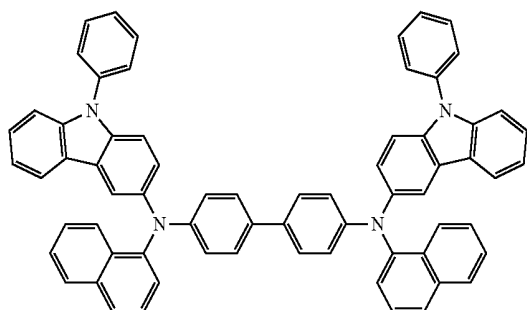
HT30



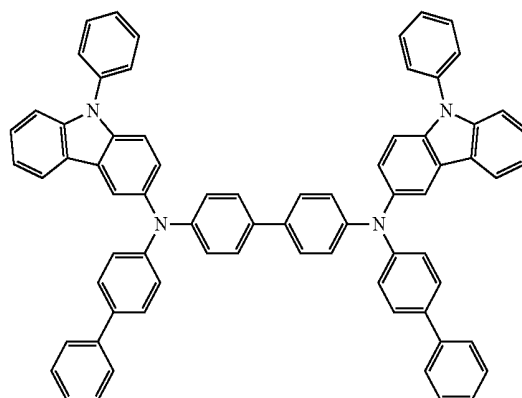
HT31



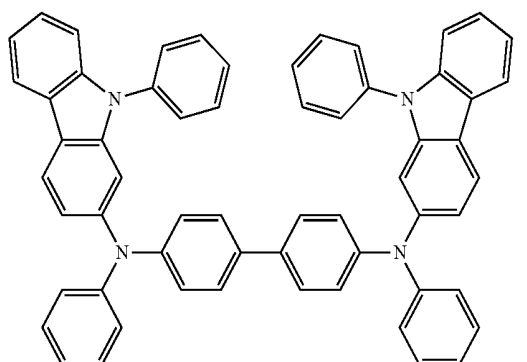
HT32



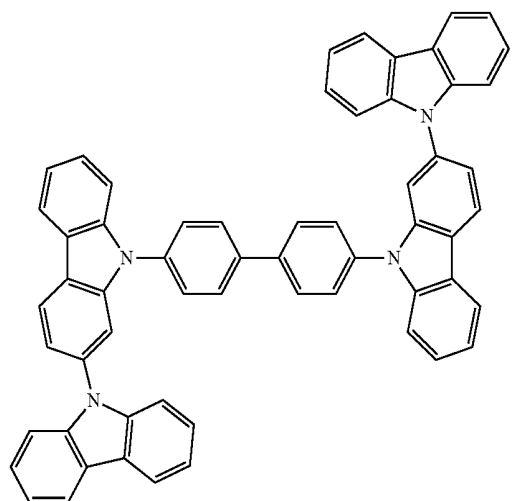
HT33

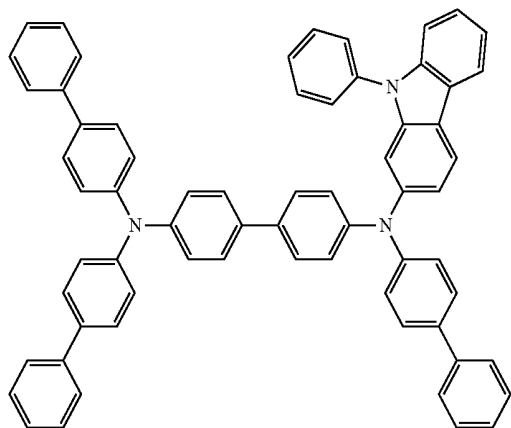


HT34

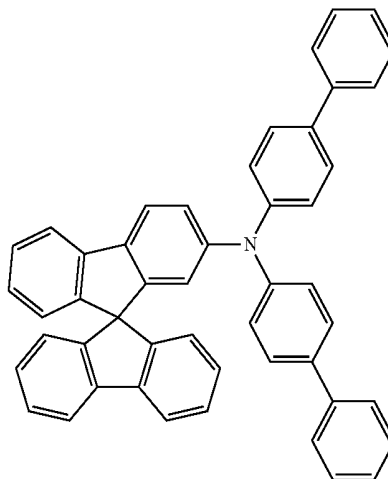


HT35

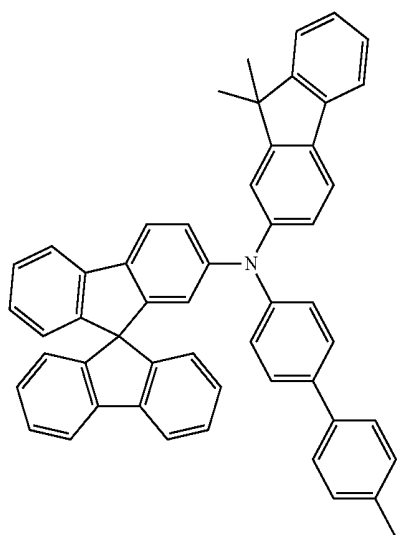


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HT36

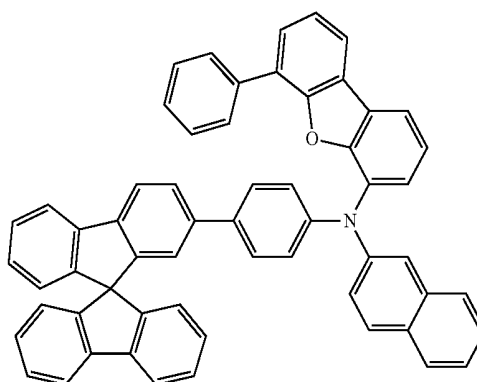
HT37



HT38



HT39



[0203] 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 9,000 Å, for example, about 100 Å to about 1,000 Å, and a thickness of the hole transport layer may be in a range of about 50 Å to about 2,000 Å, for example about 100 Å to about 1,500 Å. When the thicknesses of the hole transport region, the hole injection layer, and the hole transport layer are within these ranges, satisfactory hole transporting characteristics may be obtained without a substantial increase in driving voltage.

[0204] The emission auxiliary layer may increase light-emission efficiency by compensating for an optical resonance distance according to the wavelength of light emitted by an emission layer, and the electron blocking layer may block the flow of electrons from an electron transport region. The emission auxiliary layer and the electron blocking layer may include the materials as described above.

P-Dopant

[0205] 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.

[0206] The charge-generation material may be, for example, a p-dopant.

[0207] In one embodiment, the p-dopant has a lowest unoccupied molecular orbital (LUMO) level of about -3.5 eV or less.

[0208] The p-dopant may include at least one selected from a quinone derivative, a metal oxide, and a cyano group-containing compound, but embodiments of the present disclosure are not limited thereto.

[0209] For example, the p-dopant may include at least one selected from:

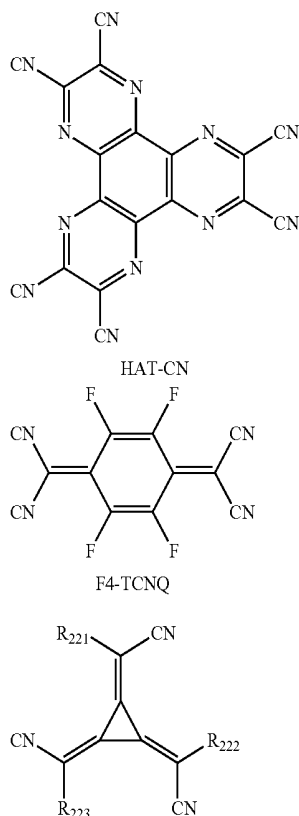
[0210] a quinone derivative, such as tetracyanoquinodimethane (TCNQ) or 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F4-TCNQ);

[0211] a metal oxide, such as tungsten oxide or molybdenum oxide;

[0212] 1,4,5,8,9,12-hexaazatriphenylene-hexacarbonitrile (HAT-CN); and

[0213] a compound represented by Formula 221 below,

[0214] but embodiments of the present disclosure are not limited thereto:



[0215] In Formula 221,

[0216] R_{221} to R_{223} may each independently be selected from a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6 - C_{60} aryl group, a substituted or unsubstituted C_1 - C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, wherein at least one selected from R_{221} to R_{223} may have at least one substituent selected from a cyano group, —F, —Cl, —Br, —I, a C_1 - C_{20} alkyl group substituted with —F, a C_1 - C_{20} alkyl group substituted with —Cl, a C_1 - C_{20} alkyl group substituted with —Br and a C_1 - C_{20} alkyl group substituted with —I.

Emission Layer in Organic Layer 150

[0217] When the organic light-emitting device 10 is a full-color organic light-emitting device, the emission layer may be patterned into a red emission layer, a green emission layer, or a blue emission layer, according to a sub-pixel. In one or more embodiments, the emission layer may have a

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

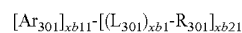
[0218] The emission layer may include a host and a dopant. The dopant may include at least one selected from a phosphorescent dopant and a fluorescent dopant.

[0219] An amount of the dopant in the emission layer may be typically in a range of about 0.01 part to about 15 parts by weight based on 100 parts by weight of the host, but embodiments of the present disclosure are not limited thereto.

[0220] A thickness of the emission layer may be in a range of about 100 Å to about 1,000 Å, for example, about 200 Å to about 600 Å. When the thickness of the emission layer is within these ranges, excellent light-emission characteristics may be obtained without a substantial increase in driving voltage.

Host in Emission Layer

[0221] In one or more embodiments, the host may include a compound represented by Formula 301 below.



Formula 301

[0222] In Formula 301,

[0223] Ar_{301} may be a substituted or unsubstituted C_5 - C_{60} carbocyclic group or a substituted or unsubstituted C_1 - C_{60} heterocyclic group,

[0224] $xb11$ may be 1, 2, or 3,

[0225] L_{301} may each independently be selected from a substituted or unsubstituted C_3 - C_{10} cycloalkylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3 - C_{10} cycloalkenylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6 - C_{60} arylene group, a substituted or unsubstituted C_1 - C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group;

[0226] $xb1$ may be an integer from 0 to 5,

[0227] R_{301} may be selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1 - C_{60} alkyl group, a substituted or unsubstituted C_2 - C_{60} alkenyl group, a substituted or unsubstituted C_2 - C_{60} alkynyl group, a substituted or unsubstituted C_1 - C_{60} alkoxy group, a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6 - C_{60} aryl group, a substituted or unsubstituted C_6 - C_{60} aryloxy group, a substituted or unsubstituted C_6 - C_{60} arylthio group, a substituted or unsubstituted C_1 - C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(Q_{301})(Q_{302})(Q_{303}), —N(Q_{301})

(Q₃₀₂), —B(Q₃₀₁)(Q₃₀₂), —C(=O)(Q₃₀₁), —S(=O)₂(Q₃₀₁), and —P(=O)(Q₃₀₁)(Q₃₀₂),

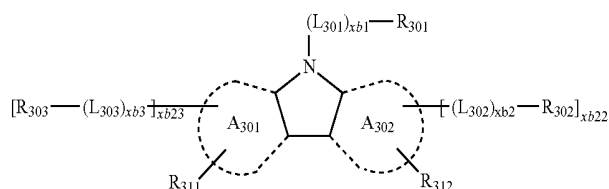
[0228] xb21 may be an integer from 1 to 5, and

[0229] Q₃₀₁ to Q₃₀₃ may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl

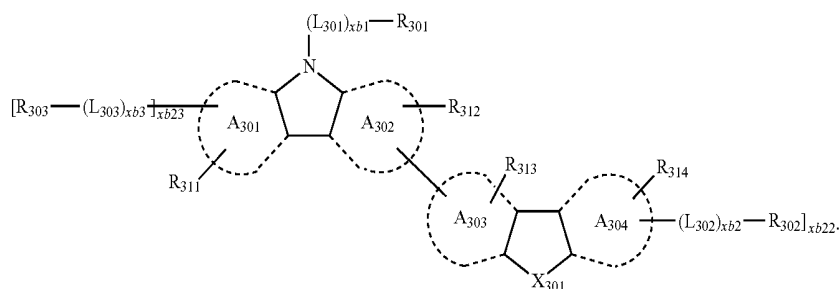
group, but embodiments of the present disclosure are not limited thereto.

[0234] In Formula 301, when xb11 is two or more, two or more Ar₃₀₁(s) may be linked via a single bond.

[0235] In one or more embodiments, the compound represented by Formula 301 may be represented by Formula 301-1 or Formula 301-2:



Formula 301-1



Formula 301-2

group, but embodiments of the present disclosure are not limited thereto.

[0230] In one embodiment, in Formula 301, Ar₃₀₁ may be selected from:

[0231] a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, and a dibenzothiophene group; and

[0232] a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, and a dibenzothiophene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂), and

[0233] Q₃₁ to Q₃₃ may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl

[0236] In Formulae 301-1 to 301-2,

[0237] A₃₀₁ to A₃₀₄ may each independently be selected from a benzene group, a naphthalene group, a phenanthrene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a pyridine group, a pyrimidine group, an indene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, an indole group, a carbazole group, a benzocarbazole group, a dibenzocarbazole group, a furan group, a benzofuran group, a dibenzofuran group, a naphthofuran group, a benzonaphthofuran group, a dinaphthofuran group, a thiophene group, a benzothiophene group, a dibenzothiophene group, a naphthothiophene group, a benzonaphthothiophene group, and a dinaphthothiophene group,

[0238] X₃₀₁ may be O, S, or N—[(L₃₀₄)_{xb4}-R₃₀₄],

[0239] R₃₁₁ to R₃₁₄ may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂),

[0240] xb22 and xb23 may each independently be 0, 1, or 2,

[0241] L₃₀₁, xb1, R₃₀₁, and Q₃₁ to Q₃₃ are the same as described above,

[0242] L₃₀₂ to L₃₀₄ may each independently be the same as described in connection with L₃₀₁,

[0243] Xb2 to Xb4 may each independently be the same as described in connection with Xb1, and

[0244] R_{302} to R_{304} may each independently be the same as described in connection with R_{301} .

[0245] For example, in Formulae 301, 301-1 and 301-2, L_{301} to L_{304} may each independently be selected from:

[0246] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylenylene group, a fluoranthenylenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylenylene group, a pentacenylenylene group, a thiophenylenylene group, a furanylenylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylenylene group, a benzothiophenylenylene group, a benzofuranylenylene group, a dibenzothiophenylenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, a pyridinylenylene group, an imidazolylenylene group, a pyrazolylenylene group, a thiazolylenylene group, an isothiazolylenylene group, an oxazolylenylene group, an isoxazolylenylene group, a thiadiazolylenylene group, an oxadiazolylenylene group, a pyrazinylenylene group, a pyrimidinylenylene group, a pyridazinylenylene group, a triazinylenylene group, a quinolinylenylene group, an isoquinolinylenylene group, a benzoquinolinylenylene group, a phthalazinylenylene group, a naphthyridinylenylene group, a quinoxalinylenylene group, a quinazolinylenylene group, a cinnolinylenylene group, a phenanthridinylenylene group, an acridinylenylene group, a phenanthrolinylenylene group, a phenazinylenylene group, a benzimidazolylenylene group, an isobenzothiazolylenylene group, a benzoxazolylenylene group, an isobenzoxazolylenylene group, a triazolylenylene group, a tetrazolylenylene group, an imidazopyrimidinylenylene group, an imidazopyrimidinylenylene group, and an azacarbazolylenylene group; and

[0247] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylenylene group, a fluoranthenylenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylenylene group, a pentacenylenylene group, a thiophenylenylene group, a furanylenylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylenylene group, a benzothiophenylenylene group, a benzofuranylenylene group, a dibenzothiophenylenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, a pyridinylenylene group, an imidazolylenylene group, a pyrazolylenylene group, a thiazolylenylene group, an isothiazolylenylene group, an oxazolylenylene group, an isoxazolylenylene group, a thiadiazolylenylene group, an oxadiazolylenylene group, a pyrazinylenylene group, a pyrimidinylenylene group, a pyridazinylenylene group, a triazinylenylene group, a quinolinylenylene group, an isoquinolinylenylene group, a benzoquinolinylenylene group, a phthalazinylenylene group, a naphthyridinylenylene group, a quinoxalinylenylene group, a quinazolinylenylene group, a cinnolinylenylene group, a phenanthridinylenylene group, an acridinylenylene group, a phenanthrolinylenylene group, a phenazinylenylene group, a benzimidazolylenylene group, an isobenzothiazolylenylene group, a benzoxazolylenylene group, an isobenzoxazolylenylene group, a triazolylenylene group, a tetrazolylenylene group, an imidazopyrimidinylenylene group, an imidazopyrimidinylenylene group, and an azacarbazolylenylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a

terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenylyl group, a pentacenylyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinylyl group, an isoquinolinylyl group, a benzoquinolinylyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinylyl group, a quinazolinylyl group, a cinnolinylyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an azacarbazolyl group, —Si(Q_{31})(Q_{32})(Q_{33}), —N(Q_{31})(Q_{32}), —B(Q_{31})(Q_{32}), —C(=O)(Q_{31}), —S(=O)₂(Q_{31}), and —P(=O)(Q_{31})(Q_{32}), and

[0248] Q_{31} to Q_{33} are the same as described above.

[0249] In one embodiment, in Formulae 301, 301-1, and 301-2, R_{301} to R_{304} may each independently be selected from:

[0250] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenylyl group, a pentacenylyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinylyl group, an isoquinolinylyl group, a benzoquinolinylyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinylyl group, a quinazolinylyl group, a cinnolinylyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group; and

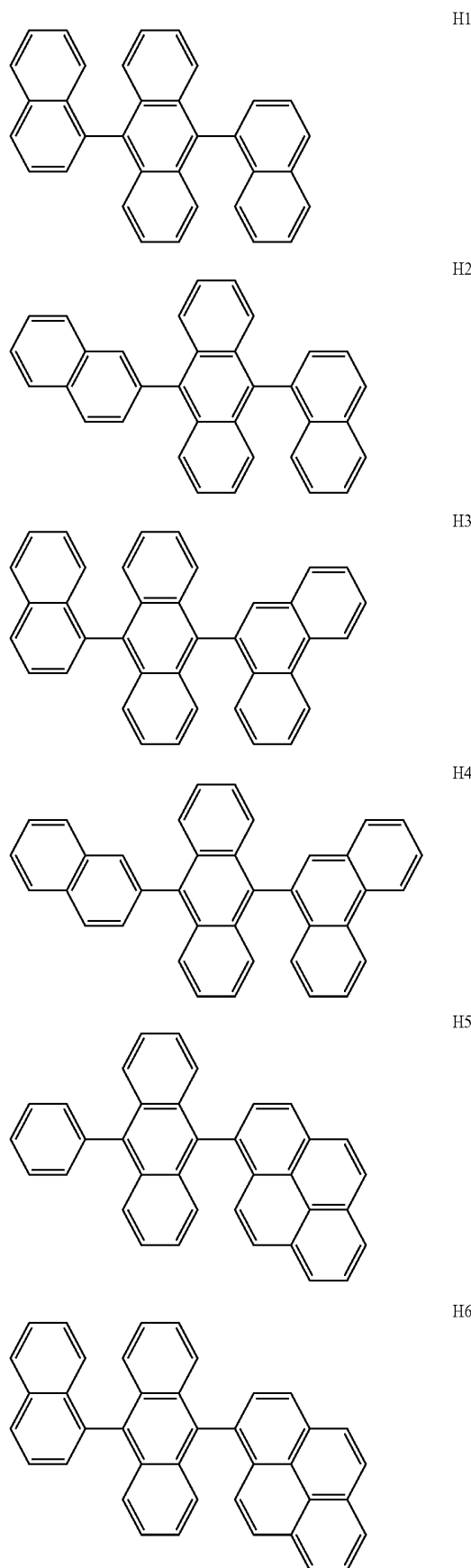
[0251] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenylyl group, a pentacenylyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl

group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an azacarbazolyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂), and

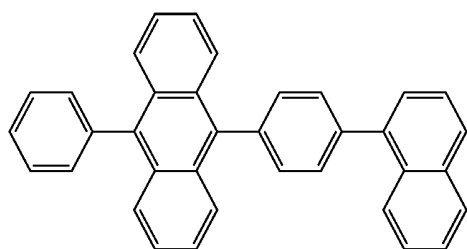
[0252] Q₃₁ to Q₃₃ are the same as described above.

[0253] In one or more embodiments, the host may include an alkaline earth metal complex. For example, the host may be selected from a Be complex (for example, Compound H55), a Mg complex, and a Zn complex.

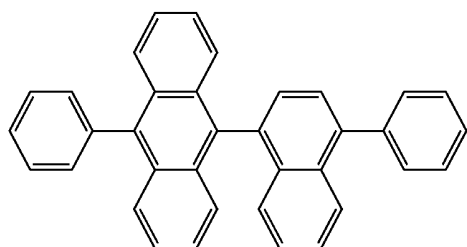
[0254] The host may include at least one selected from 9,10-di(2-naphthyl)anthracene (ADN), 2-methyl-9,10-bis(naphthalen-2-yl)anthracene (MADN), 9,10-di(2-naphthyl)-2-t-butyl-anthracene (TBADN), 4,4'-bis(N-carbazolyl)-1,1'-biphenyl (CBP), 1,3-di-9-carbazolylbenzene (mCP), 1,3,5-tri(carbazol-9-yl)benzene (TCP), and Compounds H1 to H55, but embodiments of the present disclosure are not limited thereto:



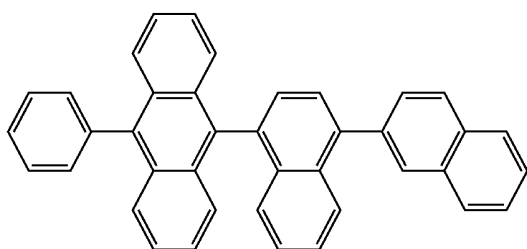
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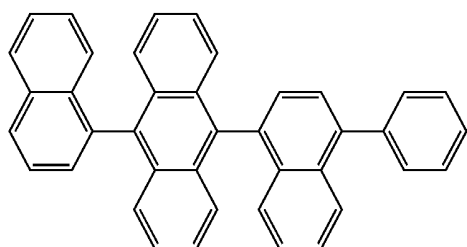
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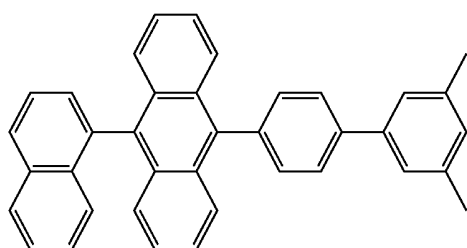
H8



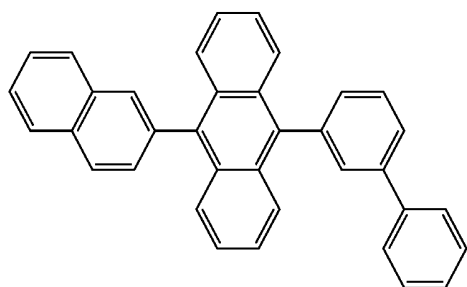
H9



H10

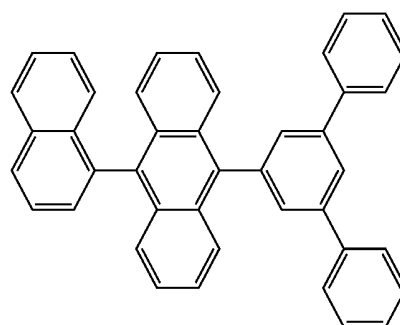


H11

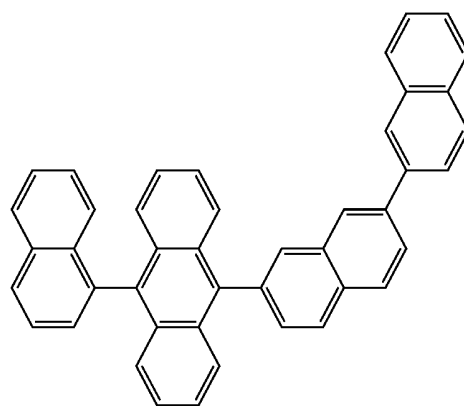


H12

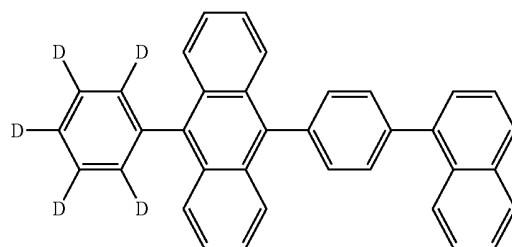
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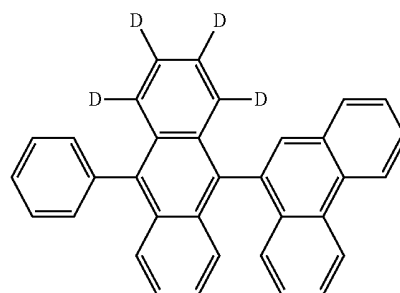
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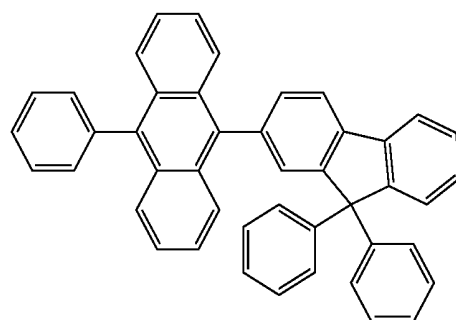
H14



H15

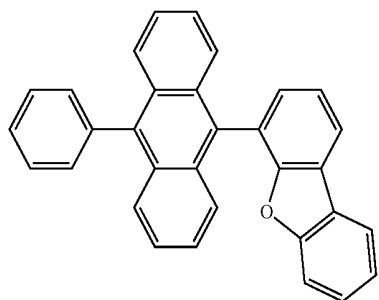


H16

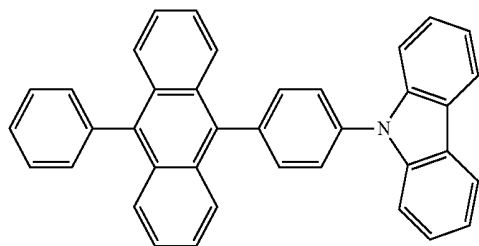


H17

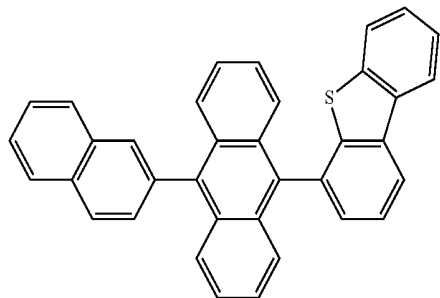
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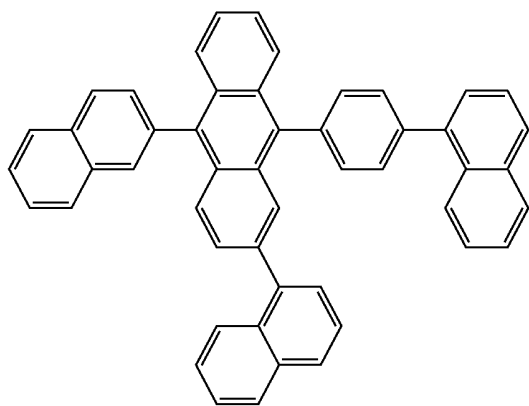
H18



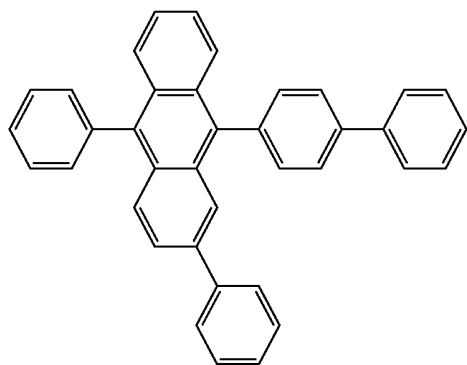
H19



H20

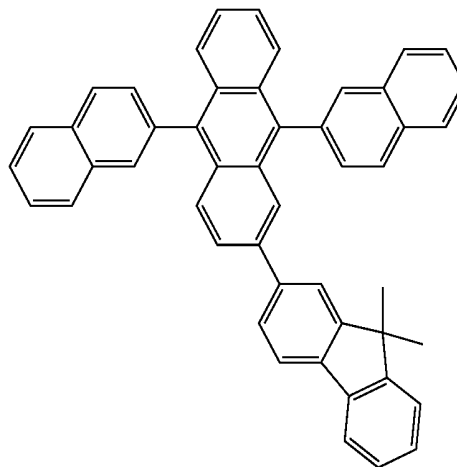


H21

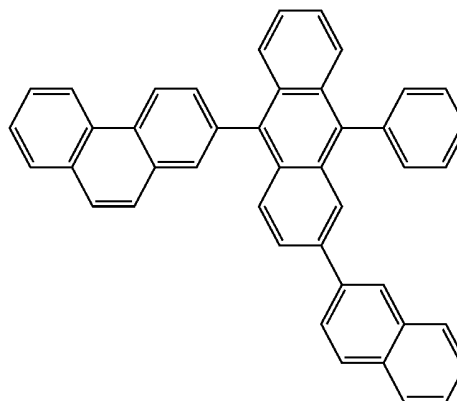


H22

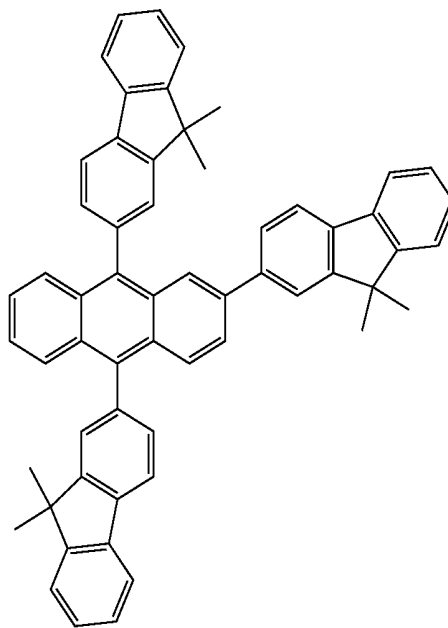
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H23

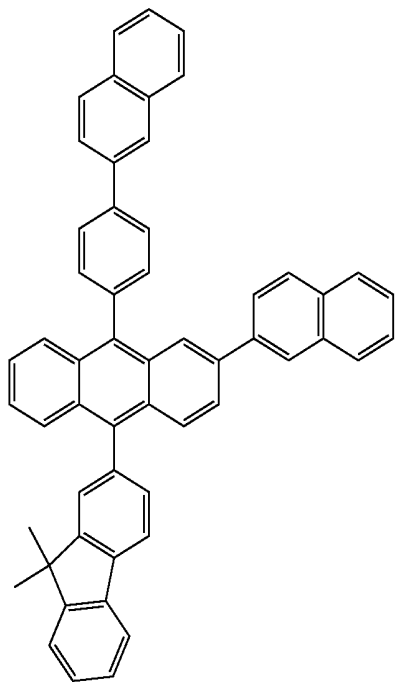


H24



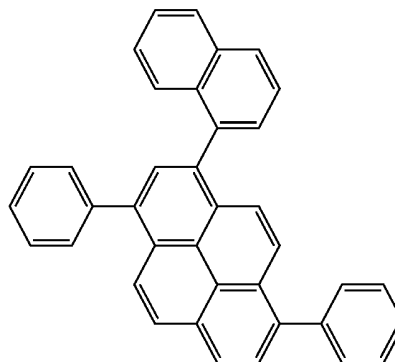
H25

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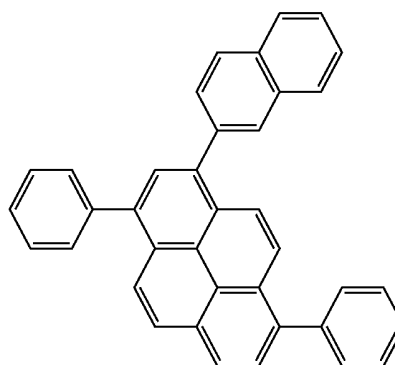


H26

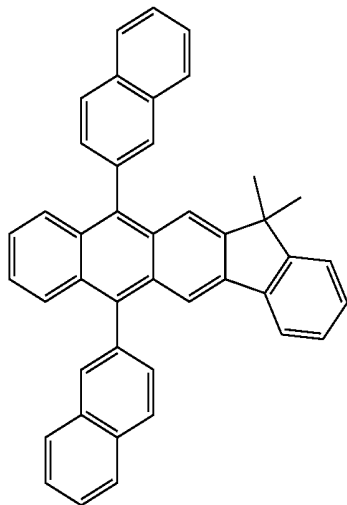
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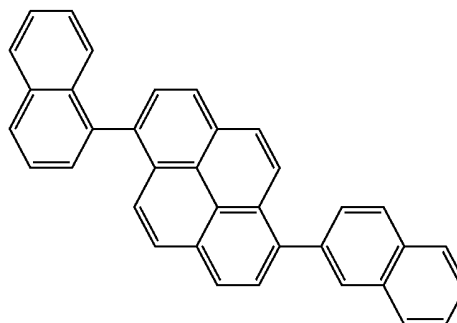
H29



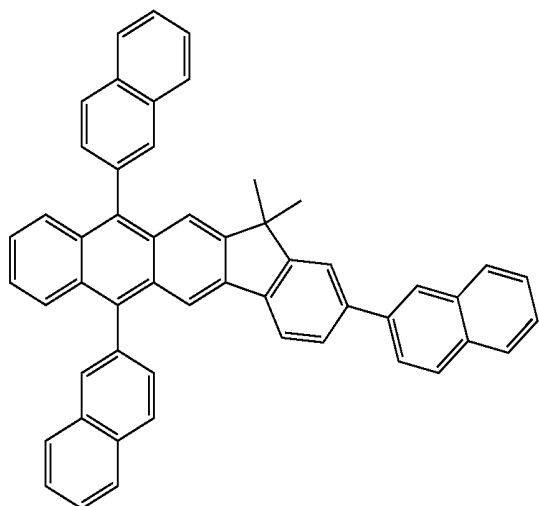
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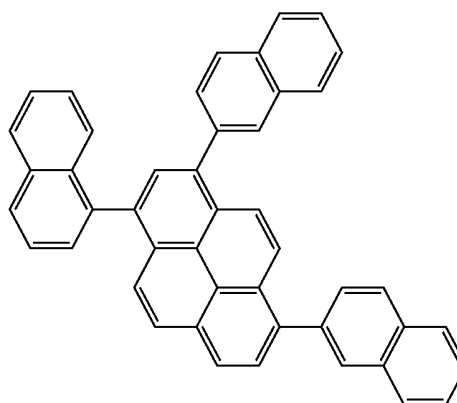
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H31



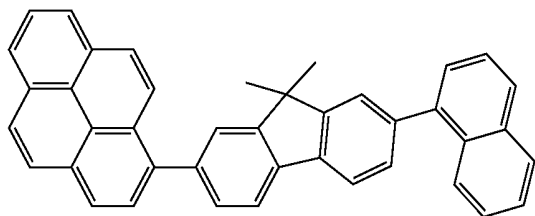
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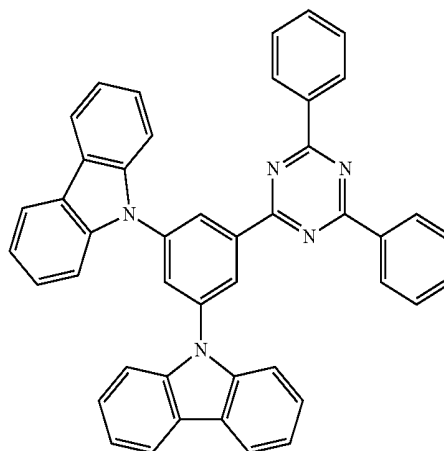
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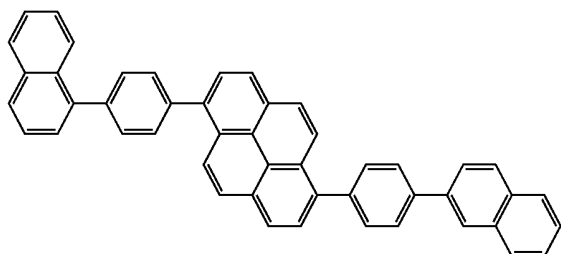


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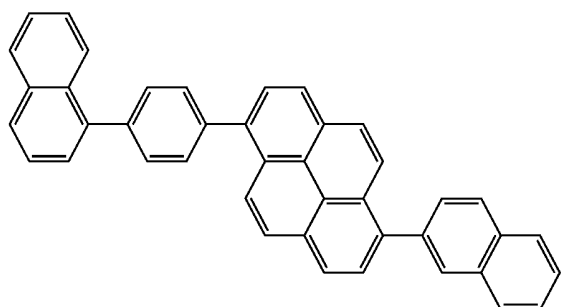
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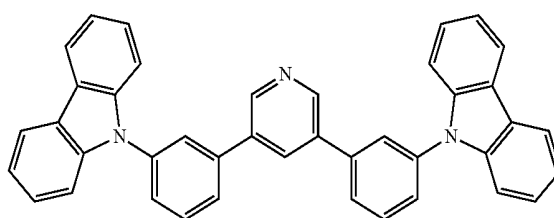
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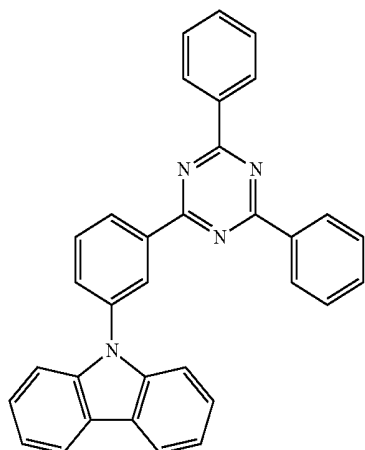
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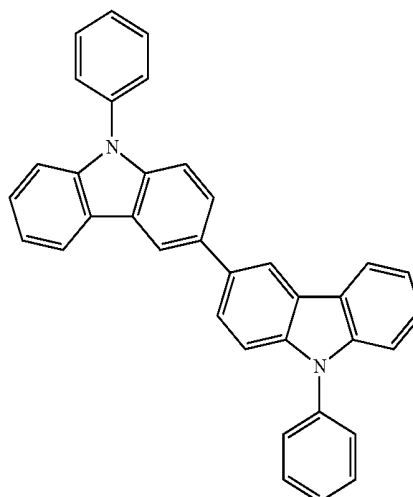
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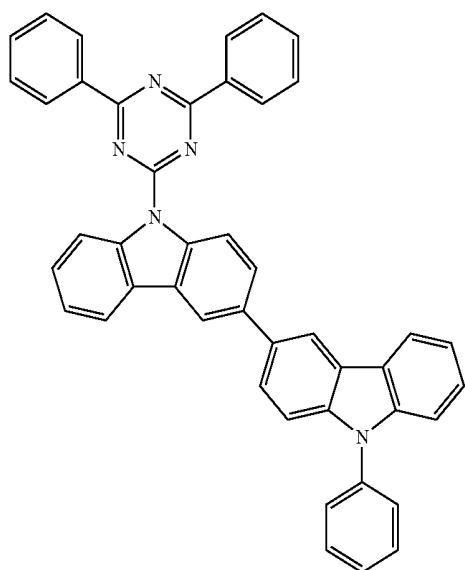
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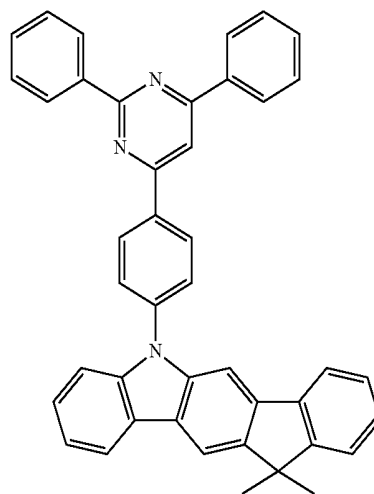
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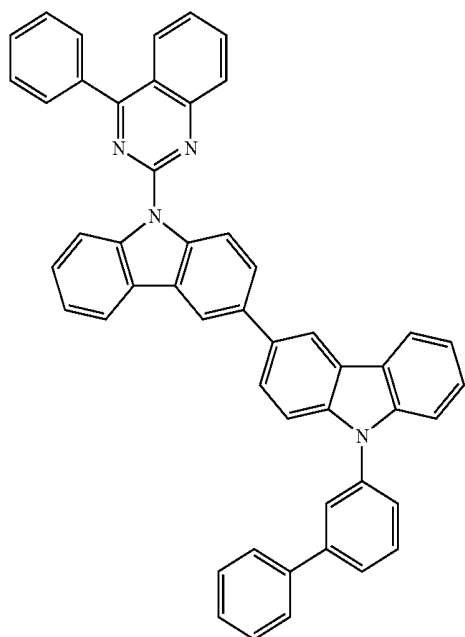
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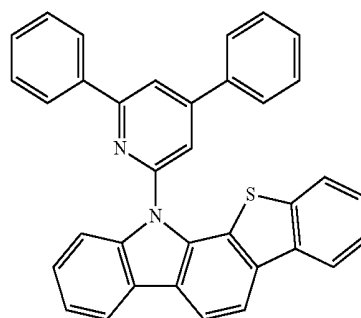
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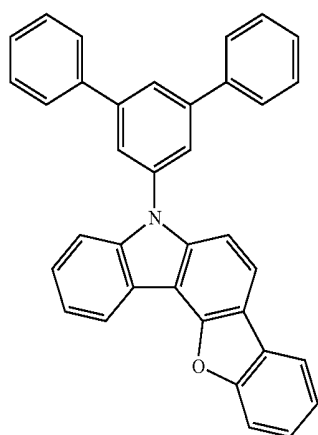
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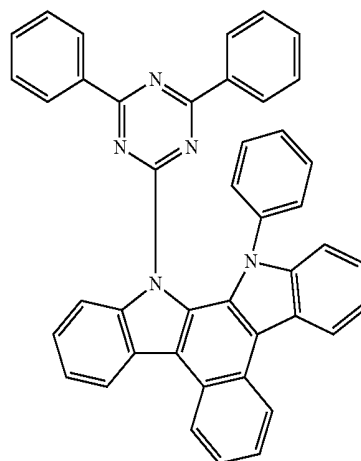
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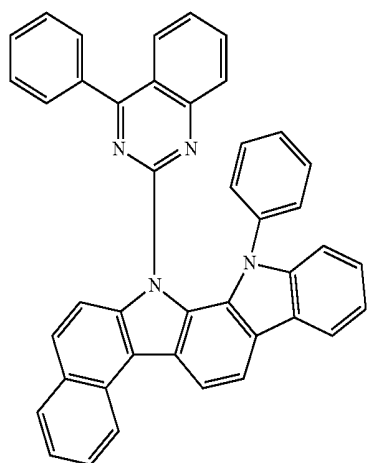


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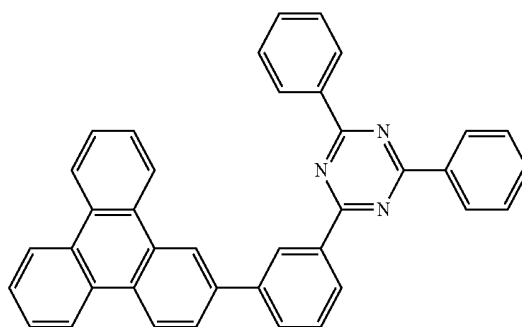
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H46



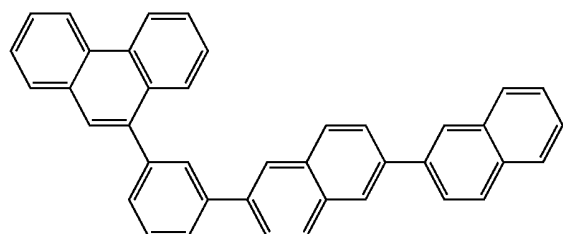
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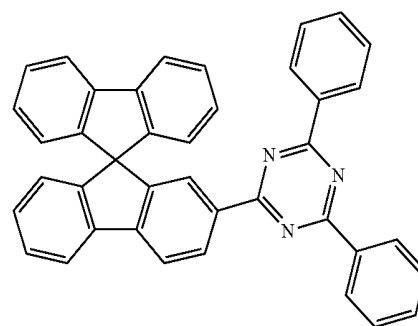


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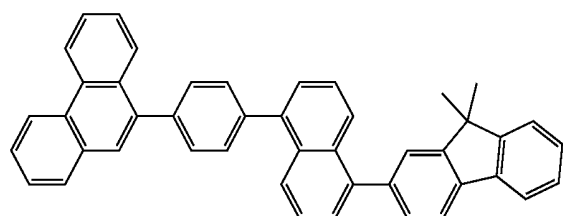
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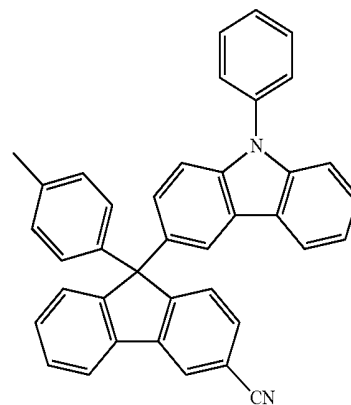
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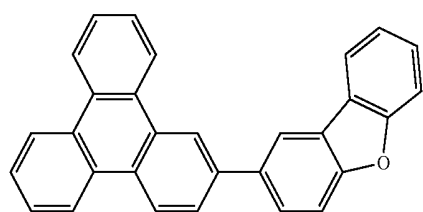
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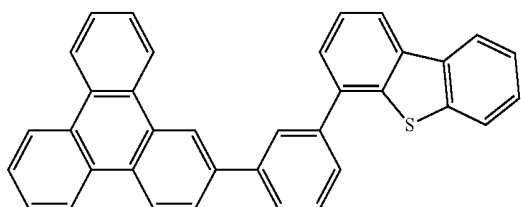
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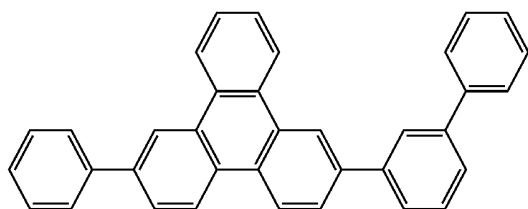
H55



H50



H51



Electron Transport Region in Organic Layer 150

[0255] The electron transport region may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

[0256] The electron transport region may include at least one selected from a buffer layer, a hole blocking layer, an electron control layer, an electron transport layer, and an electron injection layer, but embodiments of the present disclosure are not limited thereto.

[0257] For example, the electron transport region may have an electron transport layer/electron injection layer structure, a hole blocking layer/electron transport layer/electron injection layer structure, an electron control layer/electron transport layer/electron injection layer structure, or a buffer layer/electron transport layer/electron injection layer structure, wherein for each structure, constituting layers are sequentially stacked from an emission layer. However, embodiments of the structure of the electron transport region are not limited thereto.

[0258] The electron transport region (for example, a buffer layer, a hole blocking layer, an electron control layer, or an electron transport layer in the electron transport region) may include a metal-free compound containing at least one π electron-depleted nitrogen-containing ring.

[0259] The term " π electron-depleted nitrogen-containing ring" as used herein refers to a C_1 - C_{60} heterocyclic group having at least one $*-N=*$ moiety as a ring-forming moiety.

[0260] For example, the " π electron-depleted nitrogen-containing ring" may be i) a 7-membered to a 60-membered heteromonocyclic group having at least one $*-N=*$ moiety, ii) a heteropolycyclic group in which two or more 5-membered to 7-membered heteromonocyclic groups each having at least one $*-N=*$ moiety are condensed with each other, or iii) a heteropolycyclic group in which at least one of 5-membered to 7-membered heteromonocyclic groups, each having at least one $*-N=*$ moiety, is condensed with at least one C_5 - C_{60} carbocyclic group.

[0261] Examples of the π electron-depleted nitrogen-containing ring include an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, a naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, a phenanthroline group, a phenazine group, a benzimidazole group, an iso-benzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a thiadiazole group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group, but embodiments of the present disclosure are not limited thereto.

[0262] The electron transport region may include a compound represented by Formula 601:



[0263] In Formula 601,

[0264] Ar_{601} may be a substituted or unsubstituted C_5 - C_{60} carbocyclic group or a substituted or unsubstituted C_1 - C_{60} heterocyclic group,

[0265] $xe11$ may be 1, 2, or 3,

[0266] L_{601} may be selected from a substituted or unsubstituted C_3 - C_{10} cycloalkylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3 - C_{10} cycloalkenylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenylene group, a sub-

stituted or unsubstituted C_6 - C_{60} arylene group, a substituted or unsubstituted C_1 - C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0267] $xe1$ may be an integer from 0 to 5,

[0268] R_{601} may be selected from a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6 - C_{60} aryl group, a substituted or unsubstituted C_6 - C_{60} aryloxy group, a substituted or unsubstituted C_6 - C_{60} arylthio group, a substituted or unsubstituted C_1 - C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, $-\text{Si}(Q_{601})(Q_{602})(Q_{603})$, $-\text{C}(=\text{O})(Q_{601})$, $-\text{S}(=\text{O})_2(Q_{601})$, and $-\text{P}(=\text{O})(Q_{601})(Q_{602})$,

[0269] Q_{601} to Q_{603} may each independently be a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group, and

[0270] $xe21$ may be an integer from 1 to 5.

[0271] In one embodiment, at least one of $Ar_{601}(s)$ in the number of $xe11$ and/or at least one of $R_{601}(s)$ in the number of $xe21$ may include the π electron-depleted nitrogen-containing ring.

[0272] In one embodiment, in Formula 601, ring Ar_{601} may be selected from:

[0273] a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, a dibenzothiophene group, a carbazole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, a naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, a phenanthroline group, a phenazine group, a benzimidazole group, an iso-benzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a thiadiazole group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group; and

[0274] a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, a dibenzothiophene group, a carbazole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a benzoquinoline

group, a phthalazine group, a naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, a phenanthroline group, a phenazine group, a benzimidazole group, an isobenzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a thiadiazole group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂), and

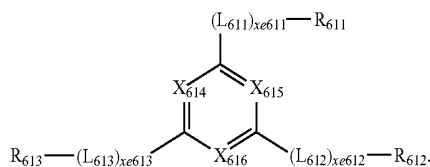
[0275] Q₃₁ to Q₃₃ may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0276] In Formula 601, when xe1 is two or more, two or more Ar₆₀₁(s) may be linked via a single bond.

[0277] In one or more embodiments, in Formula 601, Ar₆₀₁ may be an anthracene group.

[0278] In one or more embodiments, the compound represented by Formula 601 may be represented by Formula 601-1:

Formula 601-1



[0279] In Formula 601-1,

[0280] X₆₁₄ may be N or C(R₆₁₄), X₆₁₅ may be N or C(R₆₁₅), X₆₁₆ may be N or C(R₆₁₆), and at least one selected from X₆₁₄ to X₆₁₆ may be N,

[0281] L₆₁₁ to L₆₁₃ may each independently be the same as described in connection with L₆₀₁,

[0282] xe611 to xe613 may each independently be the same as described in connection with xe1,

[0283] R₆₁₁ to R₆₁₃ may each independently be the same as described in connection with R₆₀₁,

[0284] R₆₁₄ to R₆₁₆ may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0285] In one embodiment, in Formulae 601 and 601-1, L₆₀₁ and L₆₁₁ to L₆₁₃ may each independently be selected from:

[0286] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylylene group, a fluoranthenylylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylylene group, a hexacenylylene group, a pentacenylylene group, a thiophenylylene group, a furanylylene group, a carbazolylylene

group, an indolylylene group, an isoindolylylene group, a benzofuranylylene group, a benzothiophenylylene group, a dibenzofuranylylene group, a dibenzothiophenylylene group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, a pyridinylylene group, an imidazolylylene group, a pyrazolylylene group, a thiazolylylene group, an isothiazolylylene group, an oxazolylylene group, an isoxazolylylene group, a thiadiazolylylene group, an oxadiazolylylene group, a pyrazinylylene group, a pyrimidinylylene group, a pyridazinylylene group, a triazinylylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylylene group, a naphthyridinylylene group, a quinoxalinylylene group, a quinazolinylylene group, a cinnolinylene group, a phenanthridinylylene group, an acridinylylene group, a phenanthrolinylylene group, a phenazinylylene group, a benzimidazolylylene group, an isobenzothiazolylylene group, a benzoxazolylylene group, an isobenzoxazolylylene group, a triazolylylene group, a tetrazolylylene group, an imidazopyridinylylene group, an imidazopyrimidinylylene group, and an azacarbazolylylene group; and

[0287] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylylene group, a dibenzofluorenylylene group, a phenanthrenylene group, an anthracenylylene group, a fluoranthenylylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylylene group, a hexacenylylene group, a pentacenylylene group, a thiophenylylene group, a furanylylene group, a carbazolylylene group, an indolylylene group, an isoindolylylene group, a benzofuranylylene group, a benzothiophenylylene group, a dibenzofuranylylene group, a dibenzothiophenylylene group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, a pyridinylylene group, an imidazolylylene group, a pyrazolylylene group, a thiazolylylene group, an isothiazolylylene group, an oxazolylylene group, an isoxazolylylene group, a thiadiazolylylene group, an oxadiazolylylene group, a pyrazinylylene group, a pyrimidinylylene group, a pyridazinylylene group, a triazinylylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylylene group, a naphthyridinylylene group, a quinoxalinylylene group, a quinazolinylylene group, a cinnolinylene group, a phenanthridinylylene group, an acridinylylene group, a phenanthrolinylylene group, a phenazinylylene group, a benzimidazolylylene group, an isobenzothiazolylylene group, a benzoxazolylylene group, an isobenzoxazolylylene group, a triazolylylene group, a tetrazolylylene group, an imidazopyridinylylene group, an imidazopyrimidinylylene group, and an azacarbazolylylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenylyl group, a fluoranthenylyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenylyl group, a hexacenylyl group, a pentacenylyl group, a thiophenylyl group, a furanylyl group, a carbazolylyl group, an indolylyl group, an isoindolylyl group, a benzofuranylyl group, a benzothiophenylyl group, a dibenzofuranylyl group, a dibenzothiophenylyl group, a benzocarbazolylyl group, a dibenzocarbazolylyl group, a dibenzosilolylyl group, a pyridinylyl group, an imidazolylyl group, a pyrazolylyl group, a thiazolylyl group, an

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[0288] In one or more embodiments, in Formulae 601 and 601-1, xe1 and xe11 to xe13 may each independently be 0, 1, or 2.

[0289] In one or more embodiments, in Formulae 601 and 601-1, R₆₀₁ and R₆₁₁ to R₆₁₃ may each independently be selected from:

[0290] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacacenyl group, a pentacacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group;

[0291] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacacenyl group, a pentacacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a

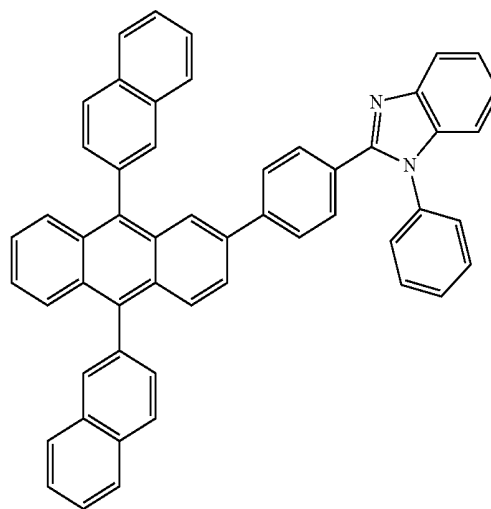
phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacacenyl group, a pentacacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group; and

[0292] —S(=O)₂(Q₆₀₁), and —P(=O)(Q₆₀₁)(Q₆₀₂), and

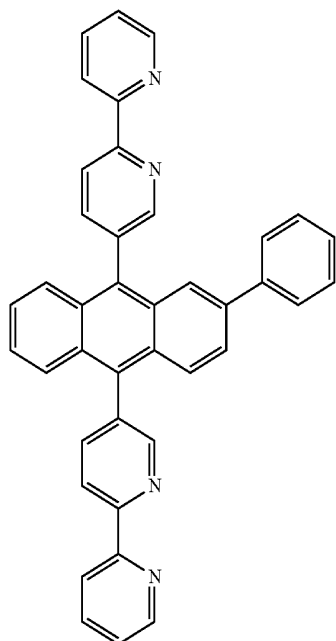
[0293] Q₆₀₁ and Q₆₀₂ are the same as described above.

[0294] The electron transport region may include at least one compound selected from Compounds ET1 to ET36, but embodiments of the present disclosure are not limited thereto:

ET1

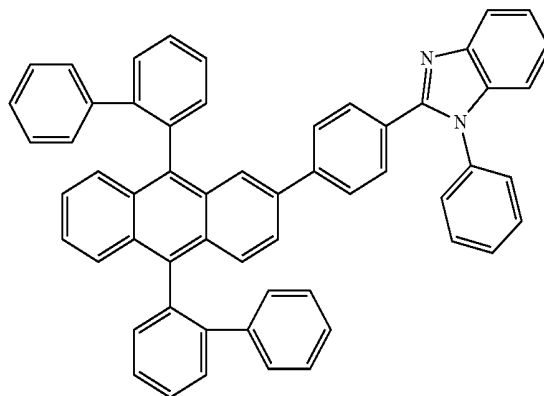


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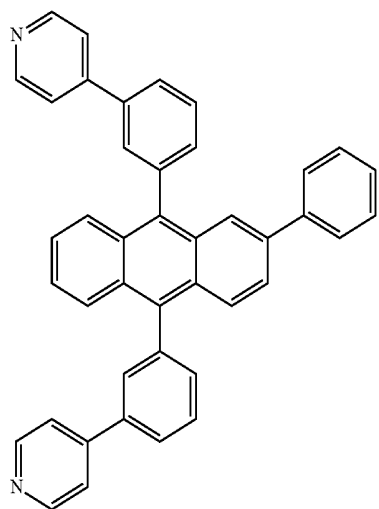
ET2

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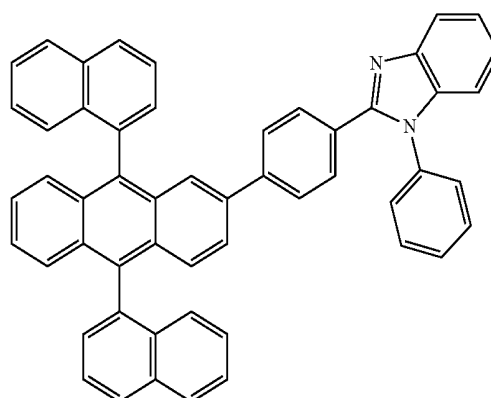


ET5

ET3

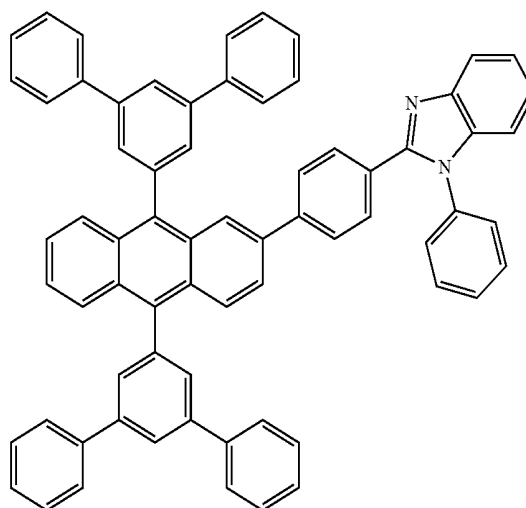
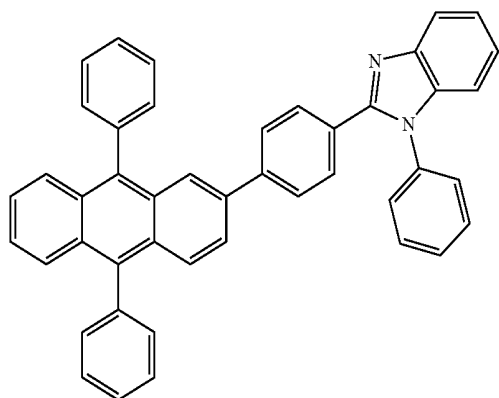


ET6



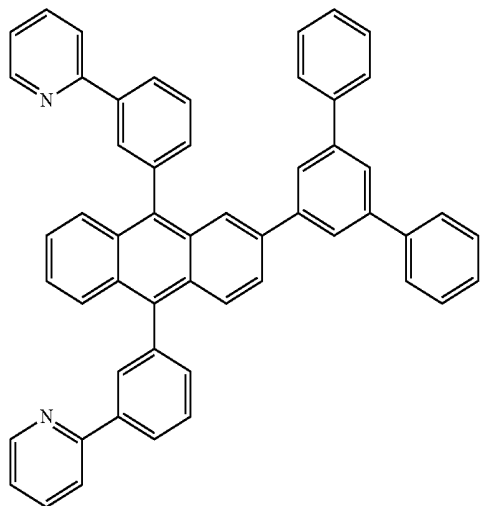
ET7

ET4



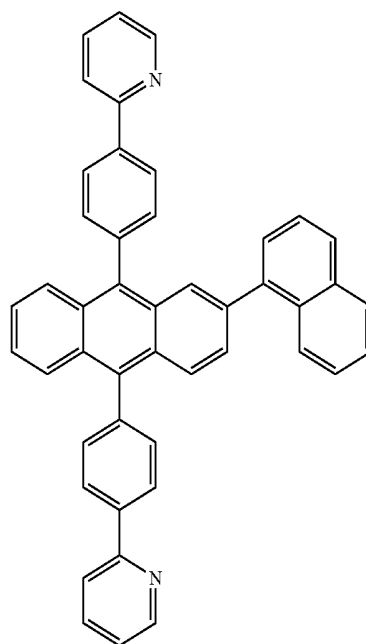
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ET8

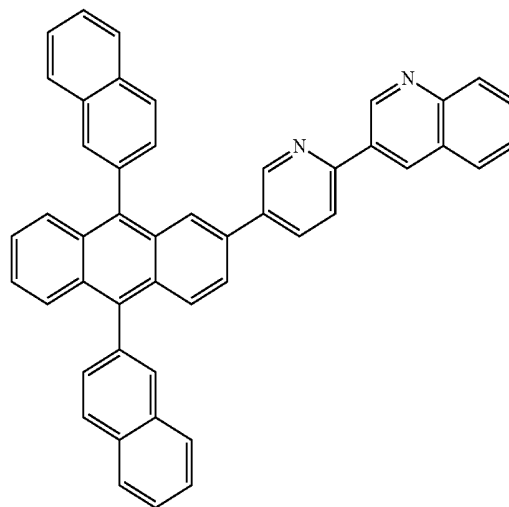


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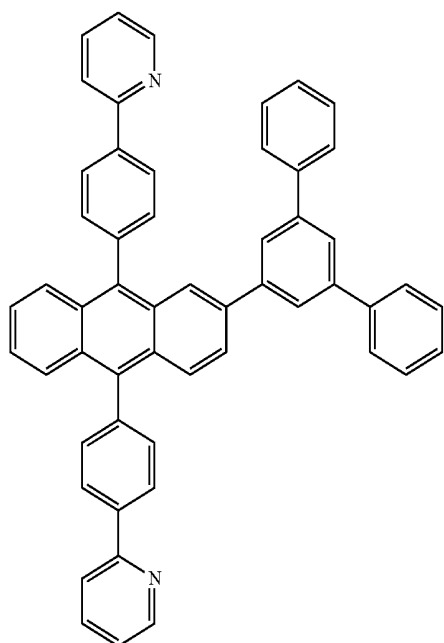
ET10



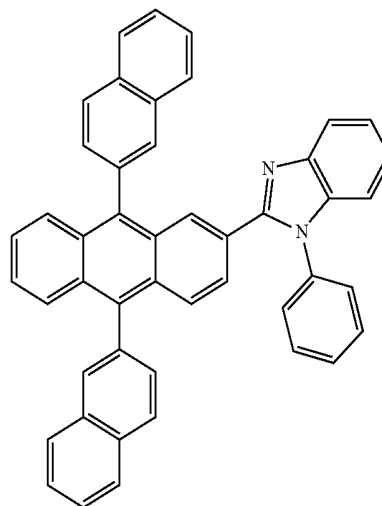
ET11



ET9

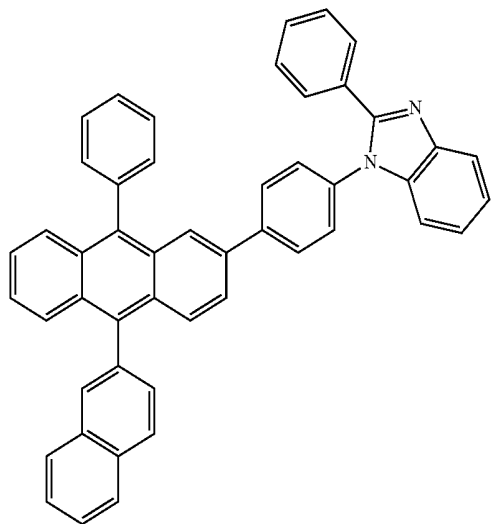


ET12



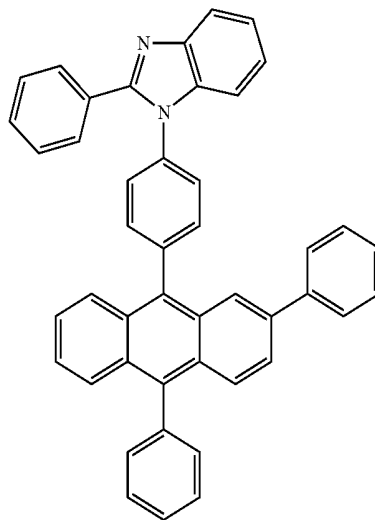
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ET13



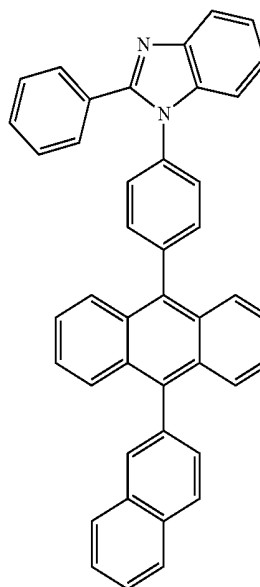
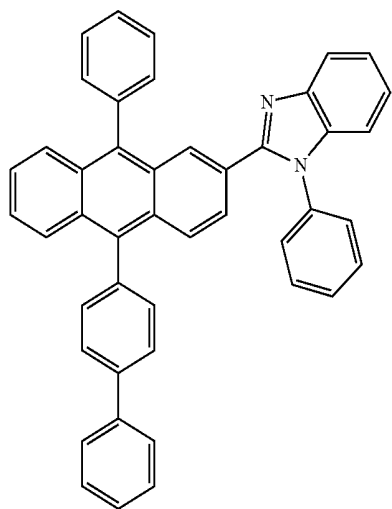
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ET16



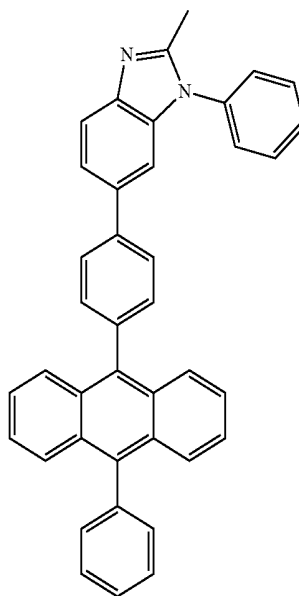
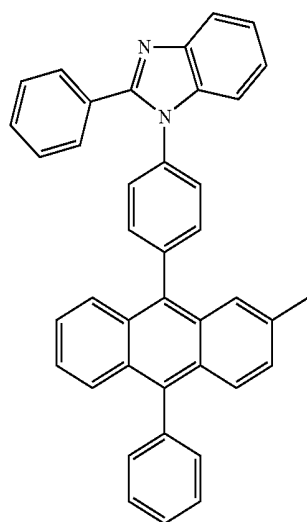
ET17

ET14

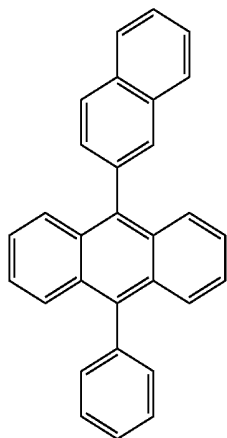


ET18

ET15

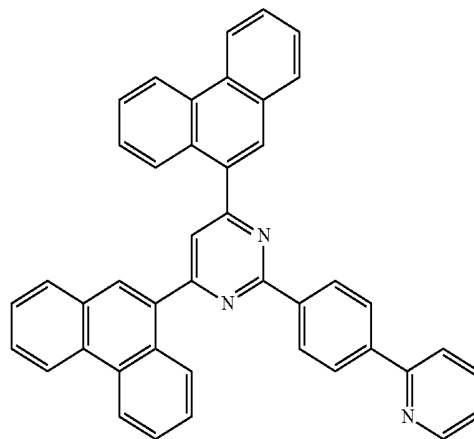


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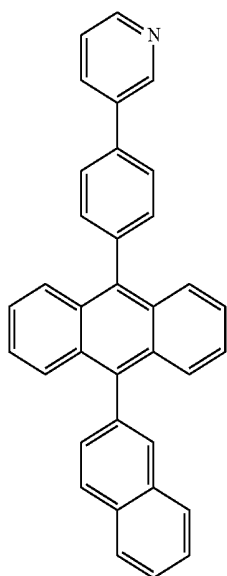
ET19

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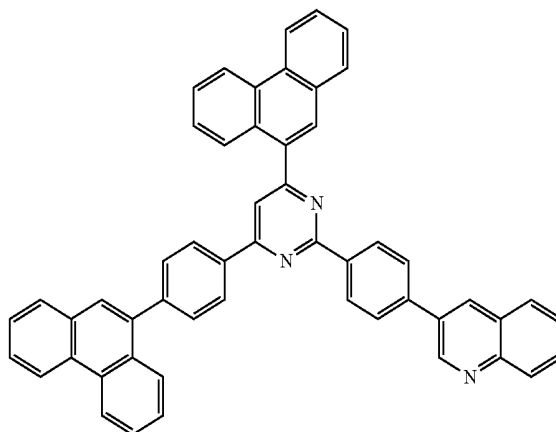


ET22

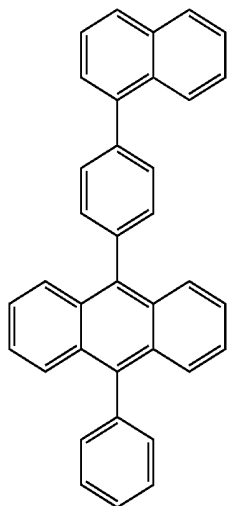
ET20



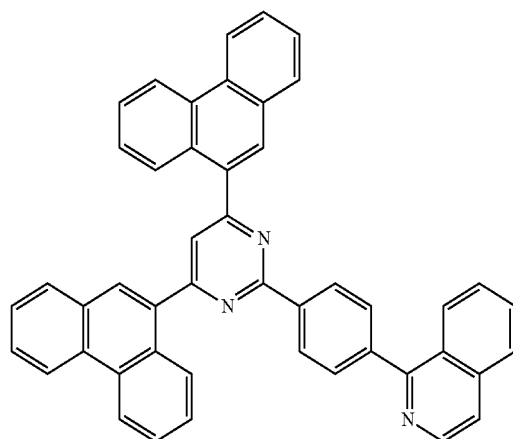
ET23



ET21

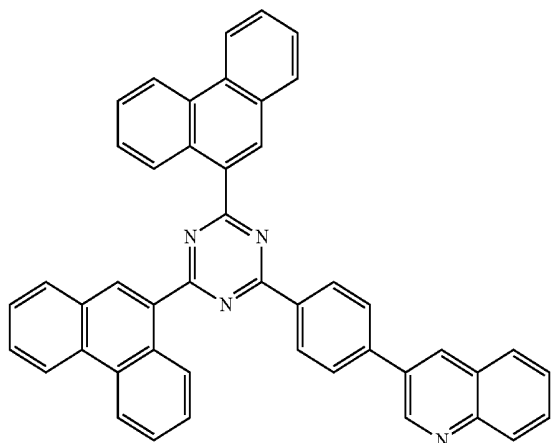


ET24



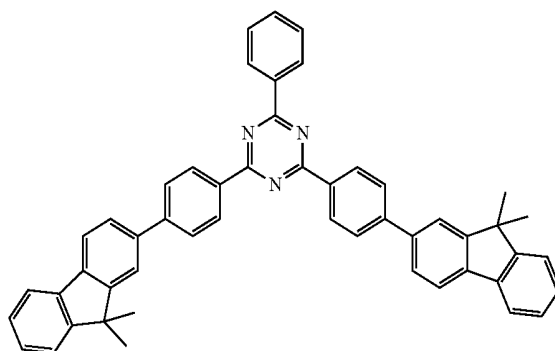
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ET25



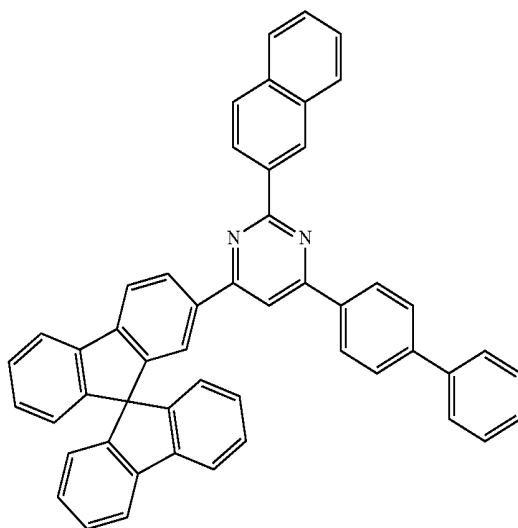
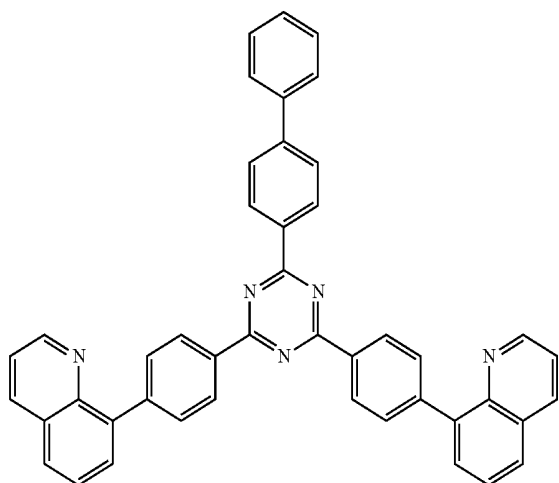
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ET28



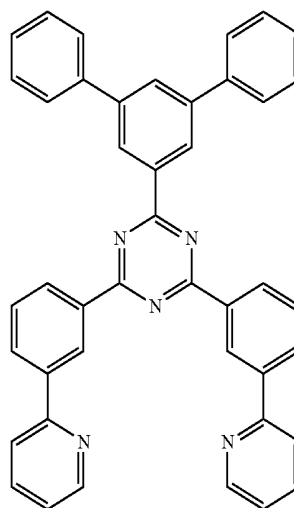
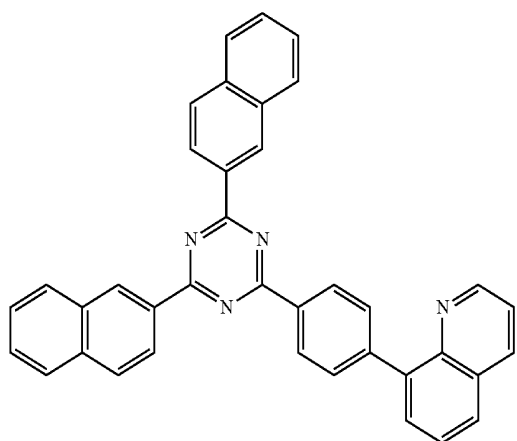
ET29

ET26

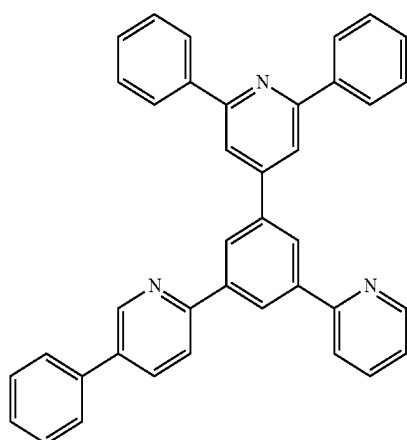


ET30

ET27

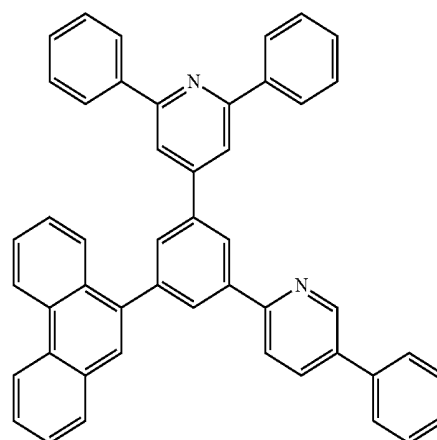


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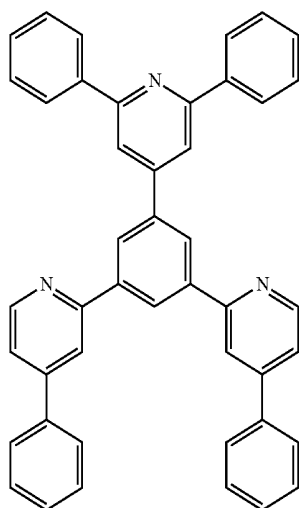
ET31

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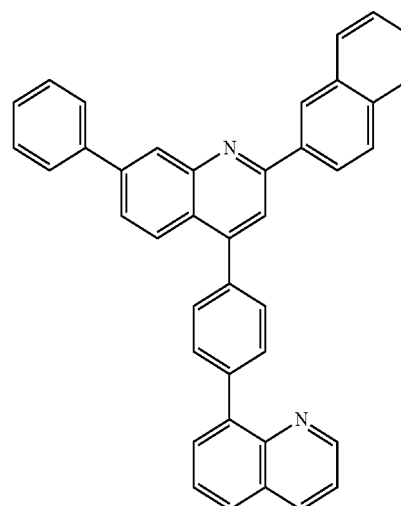


ET34

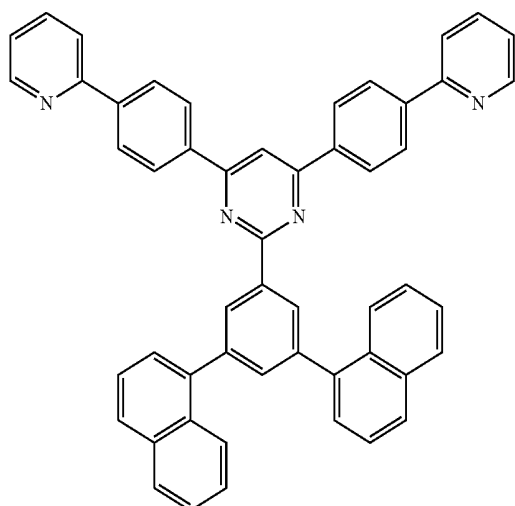
ET32



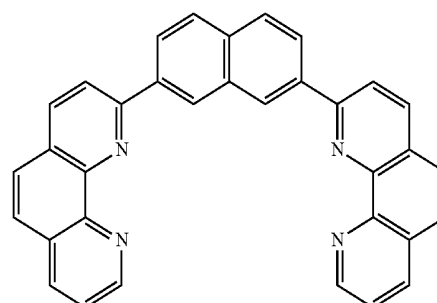
ET35



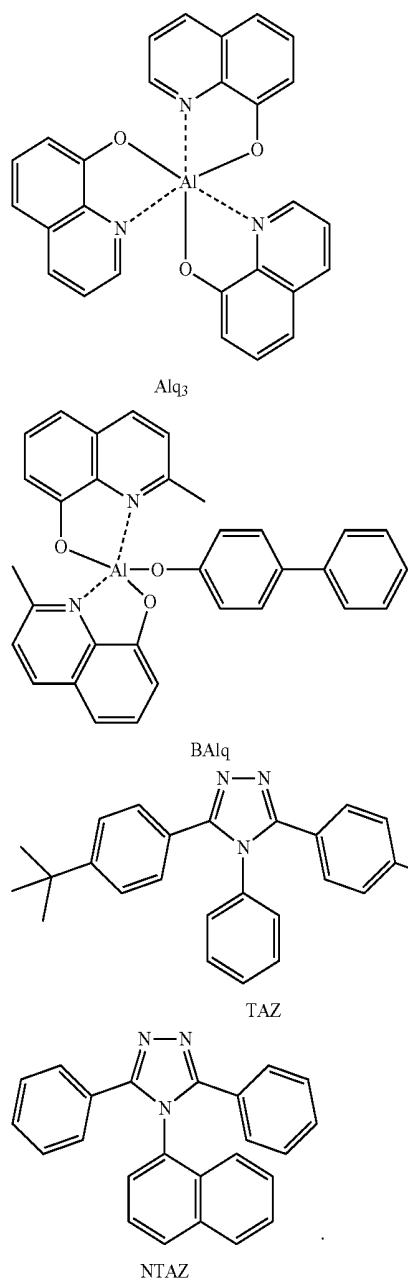
ET33



ET36



[0295] In one or more embodiments, the electron transport region may include at least one compound selected from 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP), 4,7-diphenyl-1,10-phenanthroline (Bphen), Alq3, BAlq, 3-(biphenyl-4-yl)-5-(4-tert-butylphenyl)-4-phenyl-4H-1,2,4-triazole (TAZ), and NTAZ:



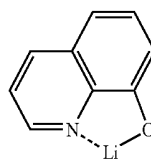
[0296] A thickness of the buffer layer, the hole blocking layer, or the electron control layer may be in a range of about 20 Å to about 1,000 Å, for example, about 30 Å to about 300 Å. When the thicknesses of the buffer layer, the hole blocking layer, and the electron control layer are within these ranges, the electron blocking layer may have excellent electron blocking characteristics or electron control characteristics without a substantial increase in driving voltage.

[0297] A thickness of the electron transport layer may be in a range of about 100 Å to about 1,000 Å, for example, about 150 Å to about 500 Å. When the thickness of the electron transport layer is within the ranges described above, the electron transport layer may have satisfactory electron transport characteristics without a substantial increase in driving voltage.

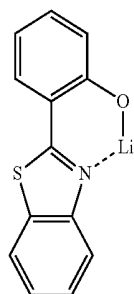
[0298] The electron transport region (for example, the electron transport layer in the electron transport region) may further include, in addition to the materials described above, a metal-containing material.

[0299] The metal-containing material may include at least one selected from alkali metal complex and alkaline earth-metal complex. The alkali metal complex may include a metal ion selected from a Li ion, a Na ion, a K ion, a Rb ion, and a Cs ion, and the alkaline earth-metal complex may include a metal ion selected from a Be ion, a Mg ion, a Ca ion, a Sr ion, and a Ba ion. A ligand coordinated with the metal ion of the alkali metal complex or the alkaline earth-metal complex may be selected from a hydroxy quinoline, a hydroxy isoquinoline, a hydroxy benzoquinoline, a hydroxy acridine, a hydroxy phenanthridine, a hydroxy phenylthiazole, a hydroxy phenylthiazole, a hydroxy diphenylthiazole, a hydroxy diphenylthiadiazole, a hydroxy diphenylthiadiazole, a hydroxy phenylpyridine, a hydroxy phenylbenzimidazole, a hydroxy phenylbenzothiazole, a bipyridine, a phenanthroline, and a cyclopentadiene, but embodiments of the present disclosure are not limited thereto.

[0300] For example, the metal-containing material may include a Li complex. The Li complex may include, for example, Compound ET-D1 (lithium quinolate, LiQ) or ET-D2:



ET-D1



ET-D2

[0301] The electron transport region may include an electron injection layer that facilitates injection of electrons from the second electrode 190. The electron injection layer may directly contact the second electrode 190.

[0302] The electron injection layer may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

[0303] The electron injection layer may include an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare earth metal complex, or any combinations thereof.

[0304] The alkali metal may be selected from Li, Na, K, Rb, and Cs. In one embodiment, the alkali metal may be Li,

Na, or Cs. In one or more embodiments, the alkali metal may be Li or Cs, but embodiments of the present disclosure are not limited thereto.

[0305] The alkaline earth metal may be selected from Mg, Ca, Sr, and Ba.

[0306] The rare earth metal may be selected from Sc, Y, Ce, Tb, Yb, and Gd.

[0307] The alkali metal compound, the alkaline earth-metal compound, and the rare earth metal compound may be selected from oxides and halides (for example, fluorides, chlorides, bromides, or iodides) of the alkali metal, the alkaline earth-metal, and the rare earth metal.

[0308] The alkali metal compound may be selected from alkali metal oxides, such as Li_2O , Cs_2O , and/or K_2O , and alkali metal halides, such as LiF, NaF, CsF, KF, LiI, NaI, CsI, and/or KI. In one embodiment, the alkali metal compound may be selected from LiF, Li_2O , NaF, LiI, NaI, CsI, and KI, but embodiments of the present disclosure are not limited thereto.

[0309] The alkaline earth-metal compound may be selected from alkaline earth-metal oxides, such as BaO, SrO, CaO , $\text{Ba}_x\text{Sr}_{1-x}\text{O}$ ($0 < x < 1$), and/or $\text{Ba}_x\text{Ca}_{1-x}\text{O}$ ($0 < x < 1$). In one embodiment, the alkaline earth-metal compound may be selected from BaO, SrO, and CaO, but embodiments of the present disclosure are not limited thereto.

[0310] The rare earth metal compound may be selected from YbF_3 , ScF_3 , ScO_3 , Y_2O_3 , Ce_2O_3 , GdF_3 , and TbF_3 . In one embodiment, the rare earth metal compound may be selected from YbF_3 , ScF_3 , TbF_3 , YbI_3 , ScI_3 , and TbI_3 , but embodiments of the present disclosure are not limited thereto.

[0311] The alkali metal complex, the alkaline earth-metal complex, and the rare earth metal complex may include an ion of alkali metal, alkaline earth-metal, and rare earth metal as described above, and a ligand coordinated with a metal ion of the alkali metal complex, the alkaline earth-metal complex, or the rare earth metal complex may be selected from hydroxy quinoline, hydroxy isoquinoline, hydroxy benzoquinoline, hydroxy acridine, hydroxy phenanthridine, hydroxy phenyloxazole, hydroxy phenylthiazole, hydroxy diphenyloxadiazole, hydroxy diphenylthiadiazol, hydroxy phenylpyridine, hydroxy phenylbenzimidazole, hydroxy phenylbenzothiazole, bipyridine, phenanthroline, and cyclopentadiene, but embodiments of the present disclosure are not limited thereto.

[0312] The electron injection layer may include (e.g., may consist of) an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare earth metal complex, or any combinations thereof, as described above. In one or more embodiments, the electron injection layer may further include an organic material. When the electron injection layer further includes an organic material, an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare earth metal complex, or any combinations thereof may be homogeneously or non-homogeneously dispersed in a matrix including the organic material.

[0313] A thickness of the electron injection layer may be in a range of about 1 Å to about 100 Å, for example, about 3 Å to about 90 Å. When the thickness of the electron

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

Second Electrode 190

[0314] The second electrode 190 may be disposed on the organic layer 150 having such a structure. The second electrode 190 may be a cathode which is an electron injection electrode, and in this regard, a material for forming the second electrode 190 may be selected from metal, an alloy, an electrically conductive compound, and a combination thereof, which have a relatively low work function.

[0315] The second electrode 190 may include at least one selected from lithium (Li), silver (Ag), magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), magnesium-silver (Mg—Ag), ITO, and IZO, but embodiments of the present disclosure are not limited thereto. The second electrode 190 may be a transmissive electrode, a semi-transmissive electrode, or a reflective electrode.

[0316] The second electrode 190 may have a single-layered structure, or a multi-layered structure including two or more layers.

Description of FIGS. 2 to 4

[0317] An organic light-emitting device 20 of FIG. 2 includes a first capping layer 210, a first electrode 110, an organic layer 150, and a second electrode 190 which are sequentially stacked in this stated order, an organic light-emitting device 30 of FIG. 3 includes a first electrode 110, an organic layer 150, a second electrode 190, and a second capping layer 220 which are sequentially stacked in this stated order, and an organic light-emitting device 40 of FIG. 4 includes a first capping layer 210, a first electrode 110, an organic layer 150, a second electrode 190, and a second capping layer 220.

[0318] Regarding FIGS. 2 to 4, the first electrode 110, the organic layer 150, and the second electrode 190 may be understood by referring to the description presented in connection with FIG. 1.

[0319] In the organic layer 150 of each of the organic light-emitting devices 20 and 40, light generated in an emission layer may pass through the first electrode 110, which is a semi-transmissive electrode or a transmissive electrode, and the first capping layer 210 toward the outside, and in the organic layer 150 of each of the organic light-emitting devices 30 and 40, light generated in an emission layer may pass through the second electrode 190, which is a semi-transmissive electrode or a transmissive electrode, and the second capping layer 220 toward the outside.

[0320] The first capping layer 210 and the second capping layer 220 may increase external luminescent efficiency according to the principle of constructive interference.

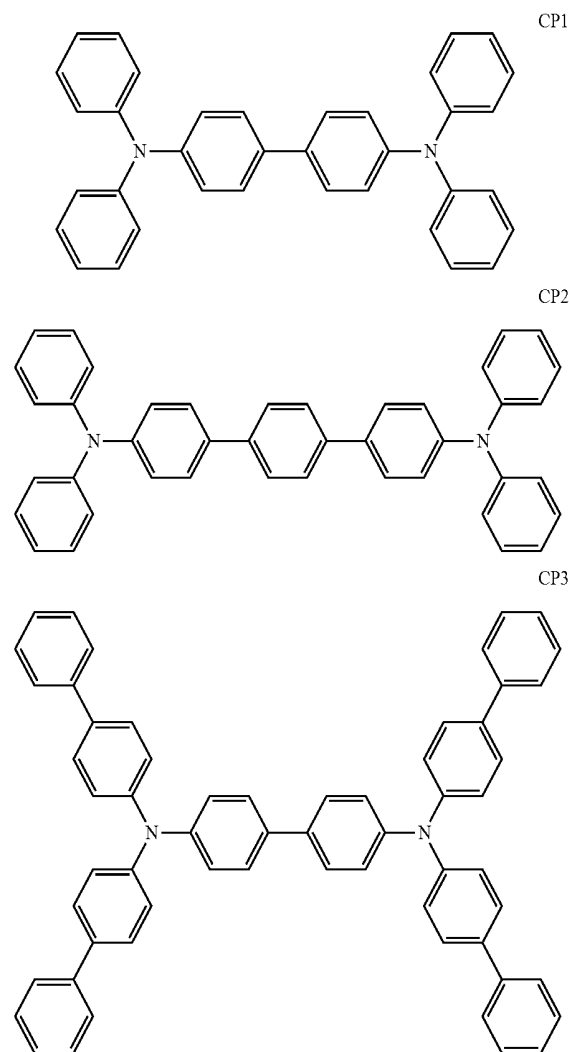
[0321] The first capping layer 210 and the second capping layer 220 may each independently be an organic capping layer including an organic material, an inorganic capping layer including an inorganic material, or a composite capping layer including an organic material and an inorganic material.

[0322] At least one selected from the first capping layer 210 and the second capping layer 220 may each independently include at least one material selected from carbocyc-

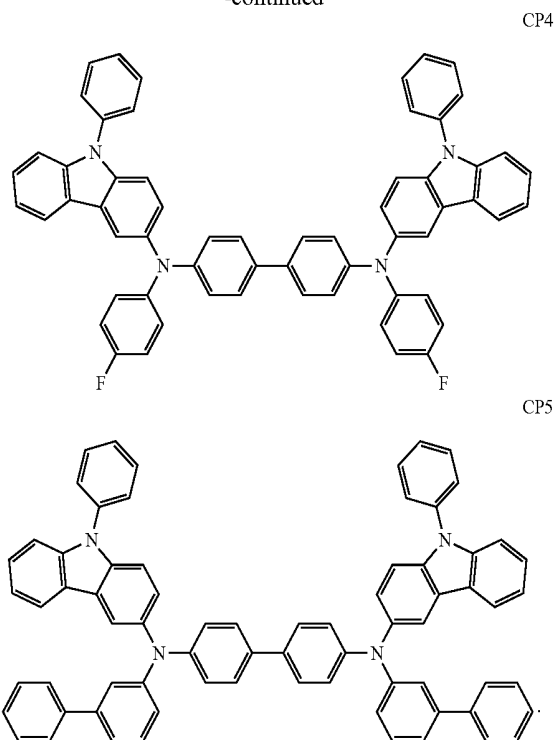
lic compounds, heterocyclic compounds, amine-based compounds, porphyrine derivatives, phthalocyanine derivatives, a naphthalocyanine derivatives, alkali metal complexes, and alkaline earth-based complexes. The carbocyclic compound, the heterocyclic compound, and the amine-based compound may be optionally substituted with a substituent containing at least one element selected from O, N, S, Se, Si, F, Cl, Br, and I. In one embodiment, at least one selected from the first capping layer 210 and the second capping layer 220 may each independently include an amine-based compound.

[0323] In one embodiment, at least one selected from the first capping layer 210 and the second capping layer 220 may each independently include the compound represented by Formula 201 or the compound represented by Formula 202.

[0324] In one or more embodiments, at least one selected from the first capping layer 210 and the second capping layer 220 may each independently include a compound selected from Compounds HT28 to HT33 and Compounds CP1 to CP5, but embodiments of the present disclosure are not limited thereto:



-continued



[0325] Hereinbefore, the organic light-emitting device according to an embodiment has been described in connection with FIGS. 1-4. However, embodiments of the present disclosure are not limited thereto.

[0326] Layers constituting the hole transport region, the emission layer, and layers constituting the electron transport region may be formed in a certain region by utilizing one or more suitable methods selected from vacuum deposition, spin coating, casting, Langmuir-Blodgett (LB) deposition, ink-jet printing, laser-printing, and laser-induced thermal imaging.

[0327] When layers constituting the hole transport region, the emission layer, and layers constituting the electron transport region are formed by vacuum deposition, for example, the vacuum deposition may be performed at a deposition temperature of about 100 to about 500° C., at a vacuum degree of about 10⁻⁸ to about 10⁻³ torr, and at a deposition rate of about 0.01 to about 100 Å/sec by taking into account a material to be included in a layer to be formed, and the structure of a layer to be formed.

[0328] When layers constituting the hole transport region, the emission layer, and layers constituting the electron transport region are formed by spin coating, the spin coating may be performed at a coating speed of about 2000 rpm to about 5000 rpm and at a heat treatment temperature of about 80° C. to 200° C. by taking into account a material to be included in a layer to be formed, and the structure of a layer to be formed.

Apparatus

[0329] The organic light-emitting device may be included in a variety of apparatuses. For example, a light-emitting

apparatus, an authentication apparatus, or an electronic apparatus including the organic light-emitting device may be provided.

[0330] The light-emitting apparatus may further include, in addition to the organic light-emitting device, a thin film transistor including a source electrode and a drain electrode. One of the source electrode and the drain electrode of the thin film transistor may be electrically connected to one of the first electrode and the second electrode of the organic light-emitting device. The light-emitting apparatus may be utilized as various displays, light sources, and/or the like.

[0331] The authentication apparatus may be, for example, a biometric authentication apparatus for authenticating an individual by utilizing biometric information of a biometric body (for example, a finger tip, a pupil, and/or the like).

[0332] The authentication apparatus may further include, in addition to the organic light-emitting device, a biometric information collector.

[0333] The electronic apparatus may be applied to personal computers (for example, a mobile personal computer), mobile phones, digital cameras, electronic organizers, electronic dictionaries, electronic game machines, medical instruments (for example, electronic thermometers, sphygmomanometers, blood glucose meters, pulse measurement devices, pulse wave measurement devices, electrocardiogram (ECG) displays, ultrasonic diagnostic devices, and/or endoscope displays), fish finders, various measuring instruments, meters (for example, meters for a vehicle, an aircraft, and a vessel), projectors, and/or the like, but embodiments of the present disclosure are not limited thereto.

General Definition of Substituents

[0334] 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 isobutyl 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 (or substantially the same) structure as the C₁-C₆₀ alkyl group.

[0335] The term “C₂-C₆₀ alkenyl group” as used herein refers to a hydrocarbon group having at least one double bond in the middle or at the terminus of the C₂-C₆₀ alkyl group, and 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 (or substantially the same) structure as the C₂-C₆₀ alkenyl group.

[0336] The term “C₂-C₆₀ alkynyl group” as used herein refers to a hydrocarbon group having at least one triple bond in the middle or at the terminus of the C₂-C₆₀ alkyl group, and examples thereof include an ethynyl group, and a propynyl group. The term “C₂-C₆₀ alkynylene group” as used herein refers to a divalent group having the same (or substantially the same) structure as the C₂-C₆₀ alkynyl group.

[0337] The term “C₁-C₆₀ alkoxy group” as used herein refers to a monovalent group represented by —OA₁₀₁ (wherein A₁₀₁ is the C₁-C₆₀ alkyl group), and examples thereof include a methoxy group, an ethoxy group, and an isopropoxy group.

[0338] The term “C₃-C₁₀ cycloalkyl group” as used herein refers to a monovalent saturated hydrocarbon monocyclic group having 3 to 10 carbon atoms, and examples thereof include a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. The term “C₃-C₁₀ cycloalkylene group” as used herein refers to a divalent group having the same (or substantially the same) structure as the C₃-C₁₀ cycloalkyl group.

[0339] The term “C₁-C₁₀ heterocycloalkyl group” as used herein refers to a monovalent monocyclic group having at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom and 1 to 10 carbon atoms, and examples thereof include a 1,2,3,4-oxatriazolidinyl group, a tetrahydrofuran group, and a tetrahydrothiophenyl group. The term “C₁-C₁₀ heterocycloalkylene group” as used herein refers to a divalent group having the same (or substantially the same) structure as the C₁-C₁₀ heterocycloalkyl group.

[0340] 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 double bond in the ring thereof and no aromaticity, and examples thereof include a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. The term “C₃-C₁₀ cycloalkenylene group” as used herein refers to a divalent group having the same (or substantially the same) structure as the C₃-C₁₀ cycloalkenyl group.

[0341] 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, Si, P, and S as a ring-forming atom, 1 to 10 carbon atoms, and at least one double bond in its ring. Non-limiting examples of the C₁-C₁₀ heterocycloalkenyl group include a 4,5-dihydro-1,2,3,4-oxatriazolyl group, a 2,3-dihydrofuran group, and a 2,3-dihydrothiophenyl group. The term “C₁-C₁₀ heterocycloalkenylene group” as used herein refers to a divalent group having the same (or substantially the same) structure as the C₁-C₁₀ heterocycloalkenyl group.

[0342] The term “C₆-C₆₀ aryl group” as used herein refers to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms, and the term “C₆-C₆₀ arylene group” as used herein refers to a divalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms. Non-limiting examples of the 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.

[0343] The term “C₁-C₆₀ heteroaryl group” as used herein refers to a monovalent group having a heterocyclic aromatic system that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, in addition to 1 to 60 carbon atoms. The term “C₁-C₆₀ heteroarylene group” as

used herein refers to a divalent group having a heterocyclic aromatic system that has at least one heteroatom selected from N, O, P, and S as a ring-forming atom, in addition to 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 condensed with each other.

[0344] The term “C₆-C₆₀ aryloxy group” as used herein refers to a group represented by —OA₁₀₂ (wherein A₁₀₂ is the C₆-C₆₀ aryl group), and the term “C₆-C₆₀ arylthio group” as used herein refers to a group represented by —SA₁₀₃ (wherein A₁₀₃ is the C₆-C₆₀ aryl group).

[0345] The term “monovalent non-aromatic condensed polycyclic group” as used herein refers to a monovalent group (for example, having 8 to 60 carbon atoms) having two or more rings condensed with each other, only carbon atoms as ring-forming atoms, and no aromaticity in its entire molecular structure. A detailed example of the monovalent non-aromatic condensed polycyclic group is a fluorenyl group. The term “divalent non-aromatic condensed polycyclic group” as used herein refers to a divalent group having the same (or substantially the same) structure as the monovalent non-aromatic condensed polycyclic group.

[0346] The term “monovalent non-aromatic condensed heteropolycyclic group” as used herein refers to a monovalent group (for example, having 1 to 60 carbon atoms) having two or more rings condensed to each other, at least one heteroatom selected from N, O, Si, P, and S, other than carbon atoms, as a ring-forming atom, and no aromaticity in its entire molecular structure. An example of the monovalent non-aromatic condensed heteropolycyclic group is a carbazolyl group. The term “divalent non-aromatic condensed heteropolycyclic group” as used herein refers to a divalent group having the same (or substantially the same) structure as the monovalent non-aromatic condensed heteropolycyclic group.

[0347] The term “C₅-C₆₀ carbocyclic group” as used herein refers to a monocyclic or polycyclic group having 5 to 60 carbon atoms in which the ring-forming atoms include only carbon atoms. The C₅-C₆₀ carbocyclic group may be an aromatic carbocyclic group or a non-aromatic carbocyclic group. The C₅-C₆₀ carbocyclic group may be a ring (such as benzene), a monovalent group (such as a phenyl group), or a divalent group (such as a phenylene group). In one or more embodiments, depending on the number of substituents connected to the C₅-C₆₀ carbocyclic group, the C₅-C₆₀ carbocyclic group may be a trivalent group or a quadrivalent group.

[0348] The term “C₁-C₆₀ heterocyclic group” as used herein refers to a group having the same (or substantially the same) structure as the C₁-C₆₀ carbocyclic group, except that as a ring-forming atom, at least one heteroatom selected

from N, O, Si, P, and S is used in addition to carbon (the number of carbon atoms may be in a range of 1 to 60).

[0349] At least one substituent of the substituted C₅-C₆₀ carbocyclic group, the substituted C₁-C₆₀ heterocyclic group, the substituted C₃-C₁₀ cycloalkylene group, the substituted C₁-C₁₀ heterocycloalkylene group, the substituted C₃-C₁₀ cycloalkenylene group, the substituted C₁-C₁₀ heterocycloalkenylene group, the substituted C₆-C₆₀ arylene group, the substituted C₁-C₆₀ heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, the substituted divalent non-aromatic condensed heteropolycyclic group, the substituted C₁-C₆₀ alkyl group, the substituted C₂-C₆₀ alkenyl group, the substituted C₂-C₆₀ alkynyl group, the substituted C₁-C₆₀ alkoxy group, the substituted C₃-C₁₀ cycloalkyl group, the substituted C₁-C₁₀ heterocycloalkyl group, the substituted C₃-C₁₀ cycloalkenyl group, the substituted C₁-C₁₀ heterocycloalkenyl group, the substituted C₆-C₆₀ aryl group, the substituted C₆-C₆₀ aryloxy group, the substituted C₆-C₆₀ arylthio group, the substituted C₁-C₆₀ heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from:

[0350] deuterium (-D), —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group;

[0351] 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, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono 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, —Si(Q₁₁)(Q₁₂)(Q₁₃), —N(Q₁₁)(Q₁₂), —B(Q₁₁)(Q₁₂), —C(=O)(Q₁₁), —S(=O)₂(Q₁₁), and —P(=O)(Q₁₁)(Q₁₂);

[0352] 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;

[0353] 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 heteropo-

lycyclic group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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, —Si(Q₂₁)(Q₂₂)(Q₂₃), —N(Q₂₁)(Q₂₂), —B(Q₂₁)(Q₂₂), —C(=O)(Q₂₁), —S(=O)₂(Q₂₁), and —P(=O)(Q₂₁)(Q₂₂); and

[0354] —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂); and

[0355] Q₁₁ to Q₁₃, Q₂₁ to Q₂₃, and Q₃₁ to Q₃₃ may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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 C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

[0356] The term “Ph” as used herein may refer to a phenyl group; the term “Me” as used herein may refer to a methyl group; the term “Et” as used herein may refer to an ethyl group; the terms “ter-Bu” or “But” as used herein may refer to a tert-butyl group; and the term “OMe” as used herein may refer to a methoxy group.

[0357] The term “biphenyl group” as used herein refers to “a phenyl group substituted with a phenyl group.” In other words, the “biphenyl group” is a substituted phenyl group having a C₆-C₆₀ aryl group as a substituent.

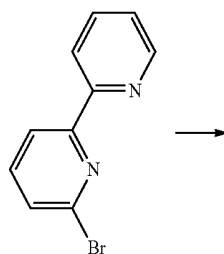
[0358] The term “terphenyl group” as used herein refers to “a phenyl group substituted with a biphenyl group.” In other words, the “terphenyl group” is a phenyl group having, as a substituent, a C₆-C₆₀ aryl group substituted with a C₆-C₆₀ aryl group.

[0359] * and *1 as used herein, unless defined otherwise, each refer to a binding site to a neighboring atom in a corresponding formula.

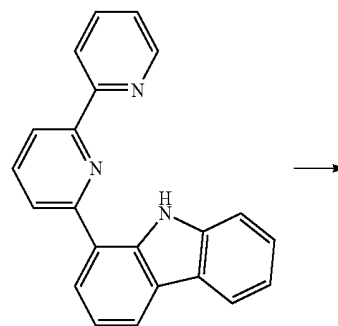
[0360] Hereinafter, a compound according to embodiments and an organic light-emitting device according to embodiments will be described in more detail with reference to Synthesis Examples and Examples. The expression “B was utilized instead of A” utilized in describing Synthesis Examples refers to that an identical number of molar equivalents of B was utilized in place of molar equivalents of A.

EXAMPLES

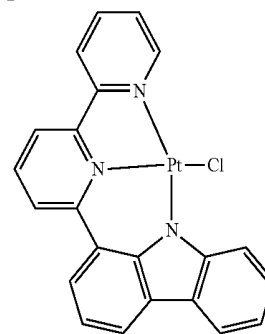
Synthesis Example 1: Synthesis of Compound 35

[0361]

Compound 1-1



Compound 1-2



Compound 35

Synthesis of Compound 1-2

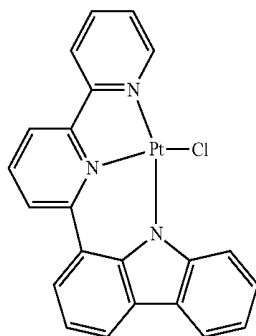
[0362] 2 g (8.5 mmol) of Compound 1-1, 2.15 g (10.2 mmol) of 1-carbazolylboronic acid, 1.0 g (25.5 mmol) of NaOH, 0.5 g (0.4 mmol) of Pd(PPh₃)₄, 30 ml of 1,4-dioxane, and 8 ml of H₂O were mixed in a nitrogen atmosphere and then stirred at a temperature of 100° C. for 12 hours. The mixture obtained after the reaction was completed was extracted therefrom by utilizing ethyl acetate, dried by utilizing MgSO₄, and then filtered to obtain an organic layer. A solvent was removed from the organic layer, and column chromatography was performed thereon to obtain 1.8 g (yield: 66%) of Compound 1-2.

Synthesis of Compound 35

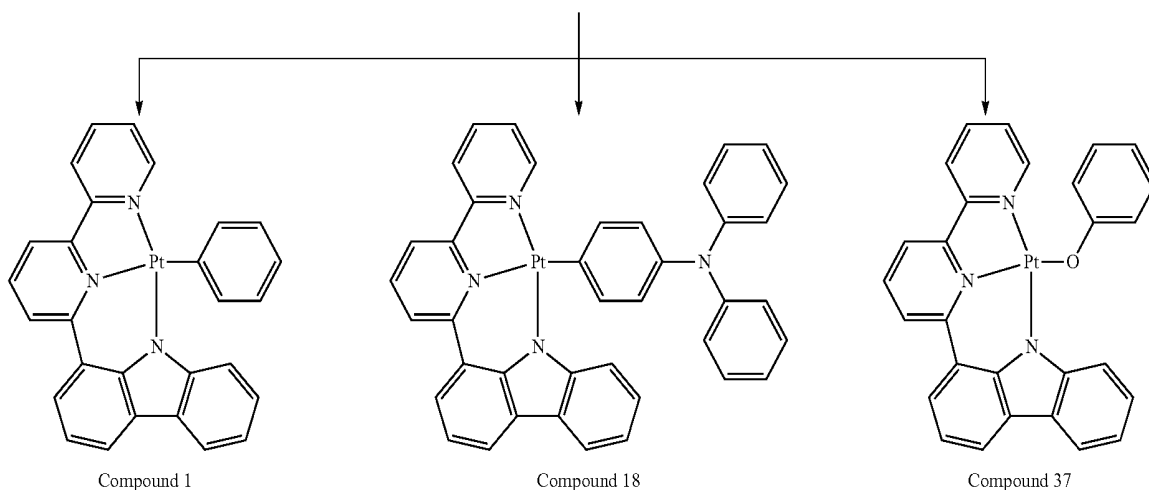
[0363] 0.5 g (1.6 mmol) of Compound 1-2, 0.7 g (1.7 mmol) of K₂PtCl₄, and 40 ml of acetic acid were mixed in a nitrogen atmosphere and then stirred at a temperature of 130° C. for 48 hours. A solid obtained after the reaction was completed was filtered, washed by utilizing methanol, water, and diethyl ether, and recrystallized by utilizing dichloromethane to obtain 0.3 g (yield: 34%) of Compound 35.

Synthesis Example 2 to 4: Synthesis of Compounds
1, 18, and 37

[0364]



Compound 35



Compound 1

Compound 18

Compound 37

Synthesis of Compound 1

[0365] 0.3 g (0.5 mmol) of Compound 35, and 5 ml of tetrahydrofuran (THF) were mixed in a nitrogen atmosphere, and 1.5 ml of phenylmagnesium bromide was added dropwise thereto. Then, the mixture was stirred at a temperature of 20° C. for 6 hours. The mixture obtained after the reaction was completed was extracted therefrom by utilizing dichloromethane, dried by utilizing MgSO₄, and then filtered to obtain an organic layer. A solvent was removed from the organic layer, and column chromatography was performed thereon to obtain 0.2 g (yield: 62%) of Compound 1.

Synthesis of Compound 18

[0366] 0.15 g (yield: 47%) of Compound 18 was synthesized in the same (or substantially the same) manner as in Synthesis of Compound 1, except that (4-(diphenylamino)phenyl)magnesium bromide was utilized instead of phenylmagnesium bromide.

Synthesis of Compound 37

[0367] 0.3 g (0.5 mmol) of Compound 35 and 20 ml of acetone were mixed in a nitrogen atmosphere, and 127 mg (0.75 mmol) of sodium phenoxide trihydrate was dissolved

in 20 ml of methanol and added dropwise to the mixture. Then, the mixture was stirred at room temperature for 10 minutes and stirred for 3 hours while applying heat thereto. A solid obtained after the reaction was completed was filtered, washed by utilizing methanol, water, and diethyl ether, and recrystallized by utilizing dichloromethane to obtain 0.17 g (yield: 55%) of Compound 37.

[0368] Synthesis methods of compounds other than Compounds shown in Table 1 may also be easily recognized by those of ordinary skill in the art by referring to the synthesis mechanisms and source materials described above.

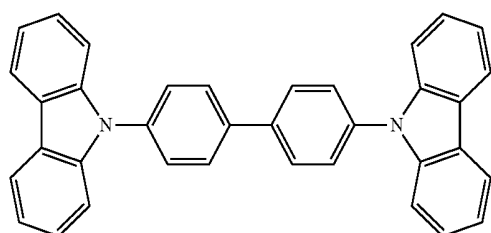
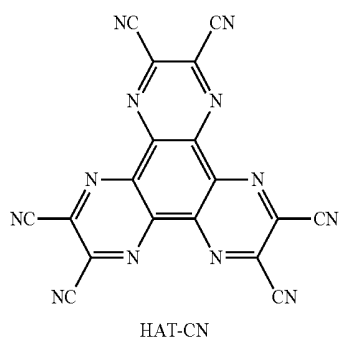
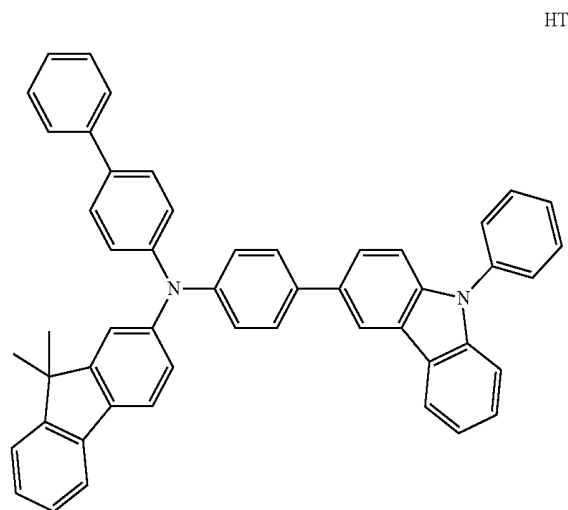
Example 1

[0369] As a substrate and an ITO anode, a Corning 15 Ω/cm² (120 nm) ITO glass substrate was cut to a size of 50 mm×50 mm×0.7 mm, sonicated with isopropyl alcohol and pure water each for 5 minutes, and then cleaned by exposure to ultraviolet rays and ozone for 30 minutes. The ITO glass substrate was provided to a vacuum deposition apparatus.

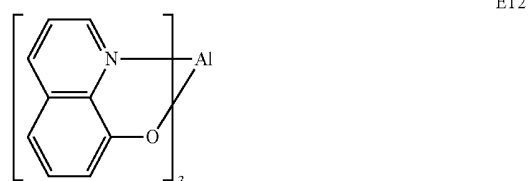
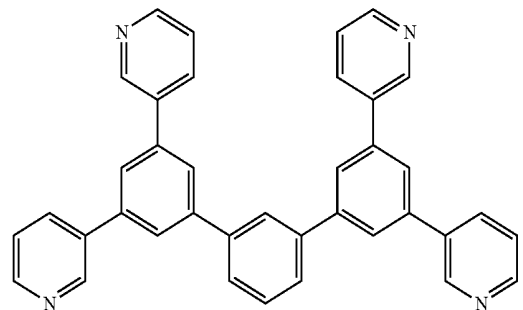
[0370] HT and HAT-CN were co-deposited on the ITO anode formed on the ITO glass substrate at a weight ratio of 99:1 to form a hole transport layer having a thickness of 120 nm.

[0371] H-1 (host) and Compound 1 (dopant) were co-deposited on the hole transport layer at a host to dopant weight ratio of 98:2 to form an emission layer having a thickness of 30 nm.

[0372] ET1 was deposited on the emission layer to form a first electron transport layer having a thickness of 5 nm, ET2 was deposited on the buffer layer to form a second electron transport layer having a thickness of 25 nm, LiF was deposited on the electron transport layer to form an electron injection layer having a thickness of 0.5 nm, and Al was vacuum-deposited on the electron injection layer to form a cathode having a thickness of 3,000 Å, thereby completing the manufacture of an organic light-emitting device.



-continued



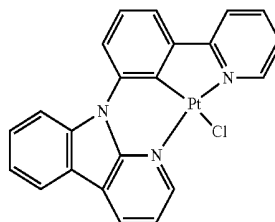
Examples 2 and 3 and Comparative Examples 1 to 3

[0373] Organic light-emitting devices were manufactured in the same (or substantially the same) manner as in Example 1, except that Compounds shown in Table 1 were each utilized instead of Compound 1 in forming an emission layer.

TABLE 1

	Dopant	Maximum emission wavelength (λ_{max})
Example 1	Compound 1	821 nm
Example 2	Compound 18	880 nm
Example 3	Compound 37	835 nm
Comparative Example 1	Compound A	543 nm
Comparative Example 2	Compound B	530 nm

Compound A



Compound B

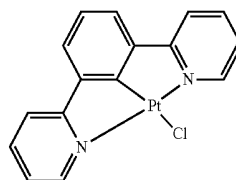
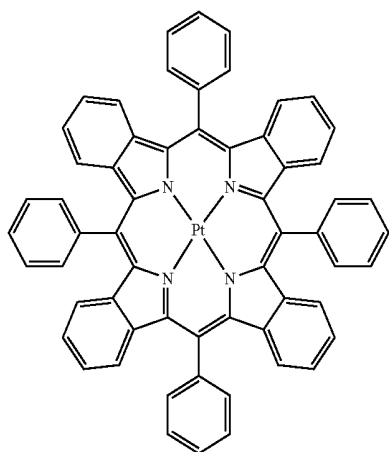


TABLE 2

	Dopant	Relative efficiency	Maximum emission wavelength (λ_{max})
Example 1	Compound 1	135%	821 nm
Example 2	Compound 18	102%	880 nm
Example 3	Compound 37	120%	835 nm
Comparative Example 3	Compound C	100%	770 nm

Compound C



[0374] Referring to Table 1, it is confirmed that the organic light-emitting devices of Examples 1 to 3 exhibit a maximum emission wavelength of (e.g., in) a near-infrared region, while the organic light-emitting devices of Comparative Examples 1 and 2 emit green light of 500 nm in a visible region.

[0375] Referring to Table 2, it is confirmed that the organic light-emitting devices of Examples 1 to 3 exhibit high efficiency, as compared with the organic light-emitting device of Comparative Example 3.

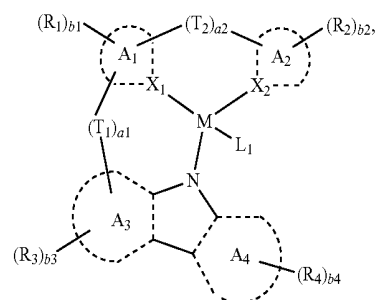
[0376] Organic light-emitting devices including such organometallic compounds are capable of emitting light of a near-infrared region while having low driving voltage, high efficiency, and long lifespan characteristics.

[0377] It should be understood that embodiments described herein should be considered in a descriptive sense only and not for purposes of limitation. Descriptions of features or aspects within each embodiment should typically be considered as available for other similar features or aspects in other embodiments.

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

What is claimed is:

1. An organometallic compound represented by Formula 1:



Formula 1

wherein, in Formula 1,

M is a transition metal,

L_1 is a monovalent organic ligand,

two bonds selected from a bond between X_1 and M, a bond between X_2 and M, and a bond between L_1 and M are each a coordinate bond, and a third bond thereof is a covalent bond,

X_1 and X_2 are each independently N or C,

A_1 to A_4 are each independently a C_5 - C_{30} carbocyclic group or a C_1 - C_{60} heterocyclic group,

T_1 and T_2 are each independently selected from $*-N[(L_{11})_{a11}-(R_{11})_{b11}]-*$, $*-B(R_{11})-*$, $*-P(R_{11})-*$, $*-C(R_{11})(R_{12})-*$, $*-Si(R_{11})(R_{12})-*$, $*-Ge(R_{11})(R_{12})-*$, $*-S-*$, $*-Se-*$, $*-O-*$, $*-C(=O)-*$, $*-S(=O)-*$, $*-S(=O)_2-*$, $*-C(R_{11})=*$, $*-C(R_{11})=*-C(R_{12})-*$, $*-C(=S)-*$, and $*-C\equiv C-*$,

L_{11} is a single bond, a substituted or unsubstituted C_5 - C_{30} carbocyclic group, or a substituted or unsubstituted C_1 - C_{60} heterocyclic group,

a_{11} is selected from 0 to 3, wherein, when a_{11} is zero, $*-(L_{11})_{a11}-*$ is a single bond,

when a_{11} is two or more, two or more L_{11} (s) are identical to or different from each other,

R_{11} and R_{12} are optionally linked to a neighboring substituent in R_1 to R_3 to form a substituted or unsubstituted C_5 - C_{30} carbocyclic group or a substituted or unsubstituted C_1 - C_{60} heterocyclic group,

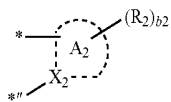
a_1 and a_2 are each independently 0, 1, 2, or 3, wherein, when a_1 is zero, $*-(T_1)_{a1}-*$ is a single bond, and when a_2 is zero, $*-(T_2)_{a2}-*$ is a single bond,

when a_1 is two or more, two or more T_1 (s) are identical to or different from each other, and when a_2 is two or more, two or more T_2 (s) are identical to or different from each other,

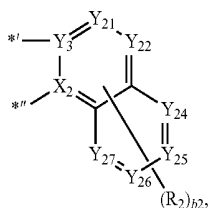
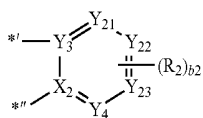
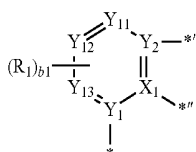
R_1 to R_4 , R_{11} , and R_{12} are each independently selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1 - C_{60} alkyl group, a substituted or unsubstituted C_2 - C_{60} alkenyl group, a substituted or unsubstituted C_2 - C_{60} alkynyl group, a substituted or unsubstituted C_1 - C_{60} alkoxy group, a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalk-

- enyl 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, —Si(Q₁)(Q₂)(Q₃), —N(Q₁)(Q₂), —B(Q₁)(Q₂), —C(=O)(Q₁), —S(=O)₂(Q₁), and —P(=O)(Q₁)(Q₂),
- neighboring substituents in R₁ to R₄ are optionally linked to form a substituted or unsubstituted C₅-C₃₀ carbocyclic group or a substituted or unsubstituted C₁-C₆₀ heterocyclic group,
- b1 to b4 and b11 are each independently selected from 1 to 6, wherein, when b1 is two or more, two or more R₁(s) are identical to or different from each other, when b2 is two or more, two or more R₂(s) are identical to or different from each other, when b3 is two or more, two or more R₃(s) are identical to or different from each other, and when b4 is two or more, two or more R₄(s) are identical to or different from each other, and when b11 is two or more, two or more R₁₁(s) are identical to or different from each other,
- at least one substituent of the substituted C₅-C₃₀ carbocyclic group, the substituted C₁-C₆₀ heterocyclic group, the substituted C₁-C₆₀ alkyl group, the substituted C₂-C₆₀ alkenyl group, the substituted C₂-C₆₀ alkynyl group, the substituted C₁-C₆₀ alkoxy group, the substituted C₃-C₁₀ cycloalkyl group, the substituted C₁-C₁₀ heterocycloalkyl group, the substituted C₃-C₁₀ cycloalkenyl group, the substituted C₁-C₁₀ heterocycloalkenyl group, the substituted C₆-C₆₀ aryl group, the substituted C₆-C₆₀ aryloxy group, the substituted C₆-C₆₀ arylthio group, the substituted C₁-C₆₀ heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group is selected from:
- deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, 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, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono 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, —Si(Q₁₁)(Q₁₂)(Q₁₃), —N(Q₁₁)(Q₁₂), —B(Q₁₁)(Q₁₂), —C(=O)(Q₁₁), —S(=O)₂(Q₁₁), and —P(=O)(Q₁₁)(Q₁₂);
- 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, a biphenyl group, and a terphenyl 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, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, 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, —Si(Q₂₁)(Q₂₂)(Q₂₃), —N(Q₂₁)(Q₂₂), —B(Q₂₁)(Q₂₂), —C(=O)(Q₂₁), —S(=O)₂(Q₂₁), and —P(=O)(Q₂₁)(Q₂₂); and
- Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂), and
- Q₁ to Q₃, Q₁₁ to Q₁₃, Q₂₁ to Q₂₃, and Q₃₁ to Q₃₃ are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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 C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.
- The organometallic compound of claim 1, wherein M in Formula 1 is selected from Zn, Cu, Pt, and Pd.
 - The organometallic compound of claim 1, wherein X₁ and X₂ in Formula 1 are each N, and the bond between X₁ and M and the bond between X₂ and M are each a coordinate bond.
 - The organometallic compound of claim 1, wherein A₁ to A₄ in Formula 1 are each independently selected from a benzene group, a naphthalene group, an anthracene group, a phenanthrene group, a phenalene group, a tetracene group, a chrysene group, a pyrene group, a fluoranthene group, a triphenylene group, a fluorene group, a benzofluorene group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, an indole group, an isoindole group, an indazole group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, a naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a carbazole group, a phenanthridine group, an acridine group, a phenanthroline group, a phenazine group, a benzimidazole group, a triazine group, a benzocarbazole group, and a dibenzocarbazole group.

is represented by Formula 2-1, and



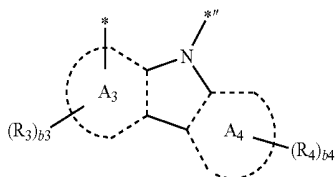
is represented by Formula 2-2 or Formula 2-3:



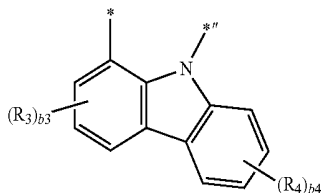
wherein, in Formulae 2-1 to 2-3, X₁, X₂, R₁, R₂, b₁, and b₂ are the same as described in Formula 1,

* and *' each indicate a binding site to T₁ or T₂ in Formula 1, and *'' indicates a binding site to M in Formula 1, and Y₁ to Y₄, Y₁₁ to Y₁₃, and Y₂₁ to Y₂₇ are each independently C or N.

10. The organometallic compound of claim 1, wherein, in Formula 1, a moiety represented by



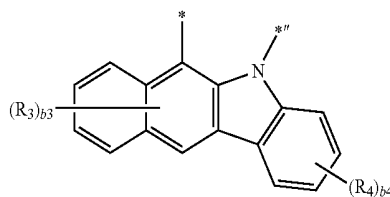
is selected from groups represented by Formulae 2-4 to 2-8:



Formula 2-4

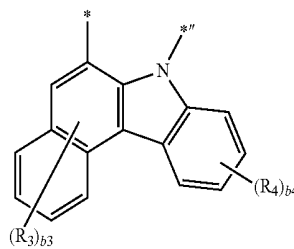
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(ii)



Formula 2-5

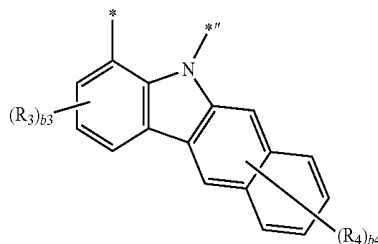
Formula 2-1



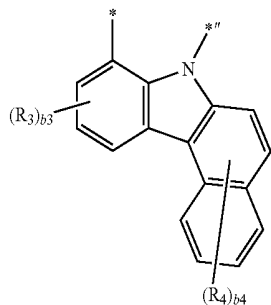
Formula 2-6

Formula 2-2

Formula 2-3



Formula 2-7

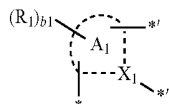


Formula 2-8

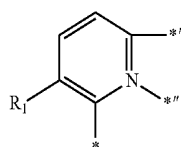
wherein, in Formulae 2-4 to 2-8, * indicates a binding site to T₁ in Formula 1, and *'' indicates a binding site to M in Formula 1, and

R₃, R₄, b₃, and b₄ are the same as described in Formula 1.

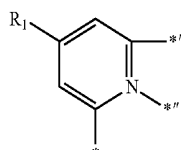
11. The organometallic compound of claim 1, wherein, in Formula 1,



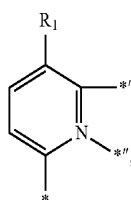
is selected from groups represented by Formulae 2-1(1) to 2-1(3):



Formula 2-1(1)



Formula 2-1(2)

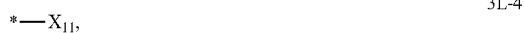
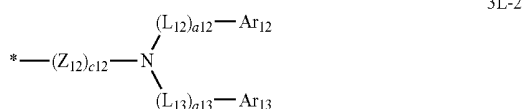


Formula 2-1(3)

wherein, in Formulae 2-1(1) to 2-1(3), * indicates a binding site to T₁ in Formula 1, *' indicates a binding site to T₂ in Formula 1, and *'' indicates a binding site to M in Formula 1, and

R₁ and b₁ are the same as described in Formula 1.

12. The organometallic compound of claim 1, wherein L₁ in Formula 1 is selected from groups represented by Formulae 3L-1 to 3L-4:



wherein, in Formulae 3L-1 to 3L-4,

Z₁₁ and Z₁₂ are each independently selected from:

a benzene group, a naphthalene group, an anthracene group, a phenanthrene group, a phenalene group, a tetracene group, a chrysene group, a pyrene group, a fluoranthene group, a triphenylene group, a fluorene group, and a benzofluorene group; and

a benzene group, a naphthalene group, an anthracene group, a phenanthrene group, a phenalene group, a tetracene group, a chrysene group, a pyrene group, a fluoranthene group, a triphenylene group, a fluorene group, and a benzofluorene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, and a C₁-C₂₀ alkoxy group,

c₁₁ and c₁₂ are each independently selected from 0 to 3, wherein, when c₁₁ is zero, *-(Z₁₁)_{c11}-* is a single bond, and when c₁₂ is zero, *-(Z₁₂)_{c12}-* is a single bond,

L₁₂ to L₁₄ are the same as described in connection with L₁₁ in Formula 1,

a₁₂ to a₁₄ are the same as described in connection with a₁₁ in Formula 1,

Ar₁₁ to Ar₁₄ are each independently selected from 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 C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group,

X₁₁ is selected from F, Cl, Br, and I,

* indicates a binding site to M in Formula 1,

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

deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, 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, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono 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, —Si(Q₁₁)(Q₁₂)(Q₁₃), —N(Q₁₁)(Q₁₂), —B(Q₁₁)(Q₁₂), —C(=O)(Q₁₁), —S(=O)₂(Q₁₁), and —P(=O)(Q₁₁)(Q₁₂);

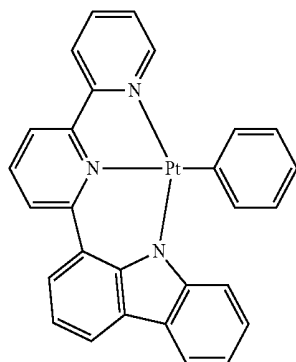
a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic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

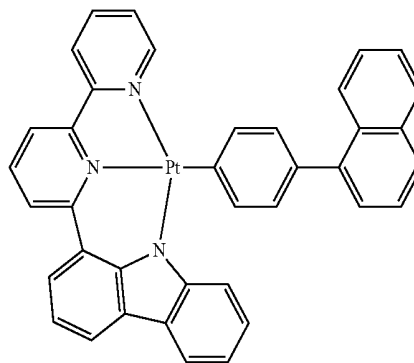
polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl 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, —Si(Q₂₁)(Q₂₂)(Q₂₃), —N(Q₂₁)(Q₂₂), —B(Q₂₁)(Q₂₂), —C(=O)(Q₂₁), —S(=O)₂(Q₂₁), and —P(=O)(Q₂₁)(Q₂₂); and —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂), and

Q₁₁ to Q₁₃, Q₂₁ to Q₂₃, and Q₃₁ to Q₃₃ are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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 C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

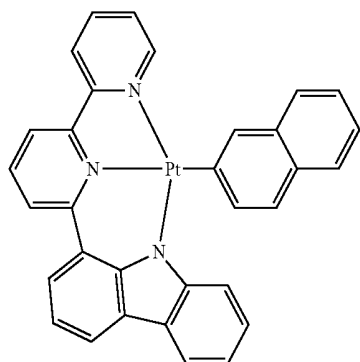
13. The organometallic compound of claim 1, wherein the organometallic compound is represented by one of Compounds 1 to 76:



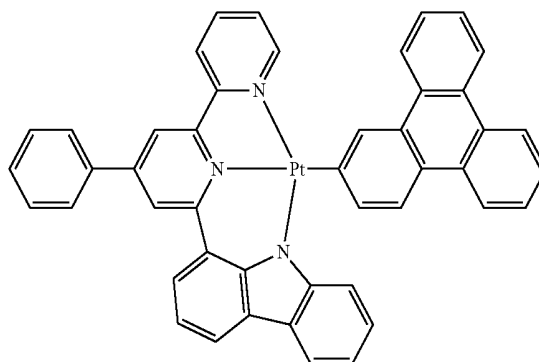
1



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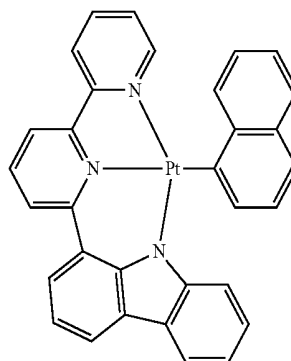


2

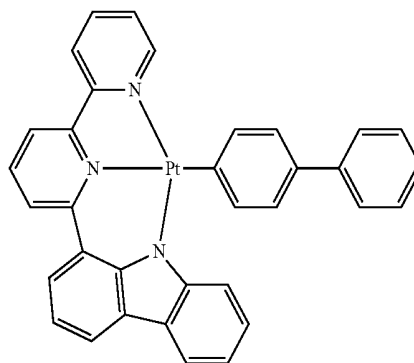


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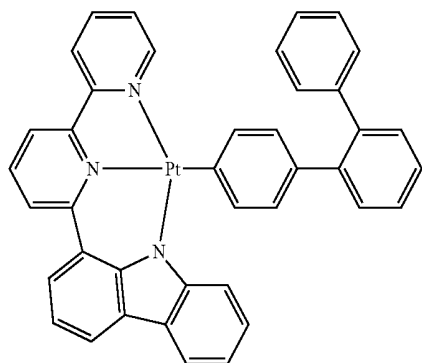


3



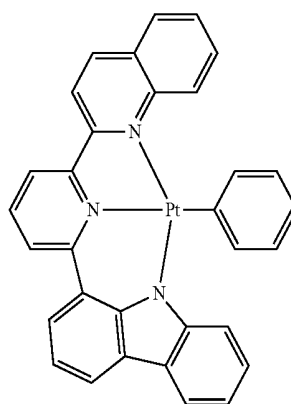
4

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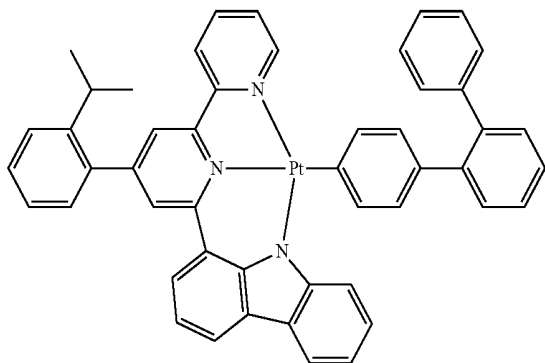
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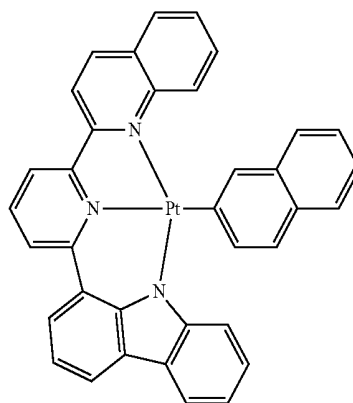


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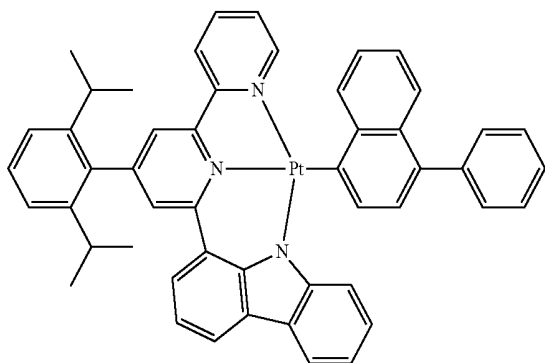


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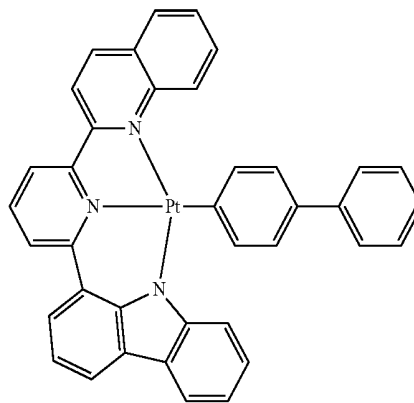
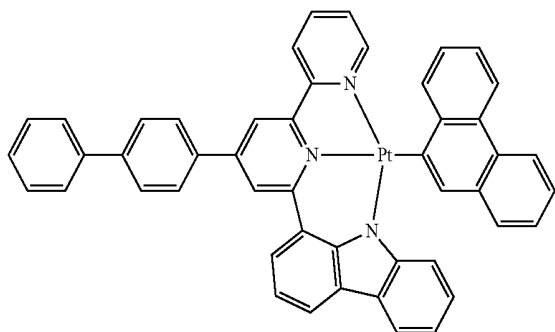
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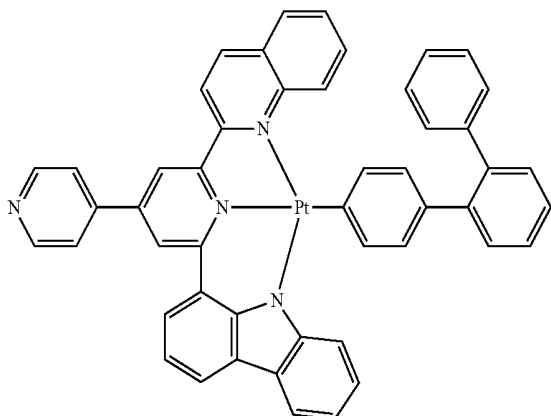
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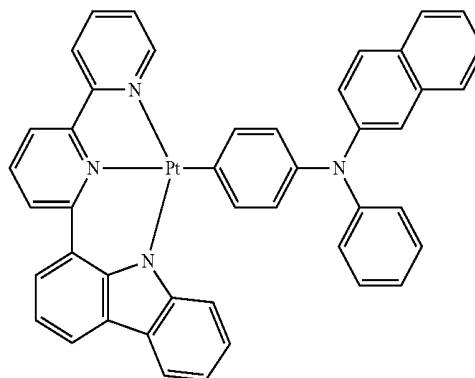
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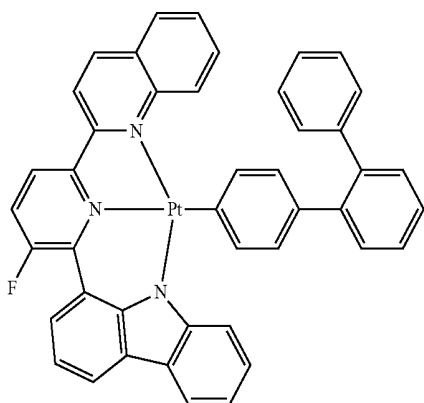


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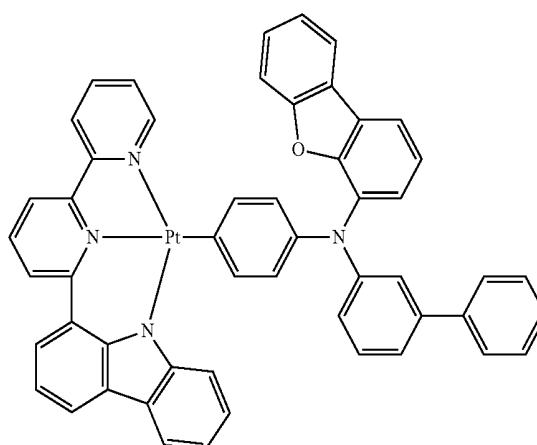
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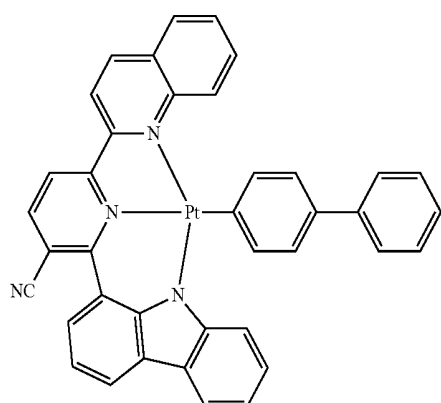
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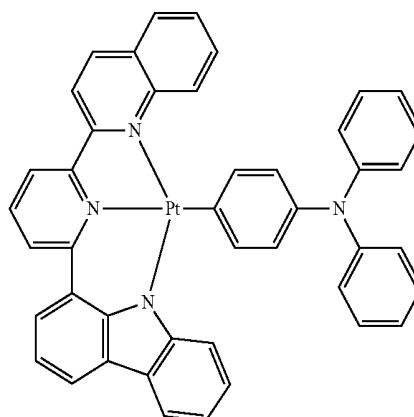
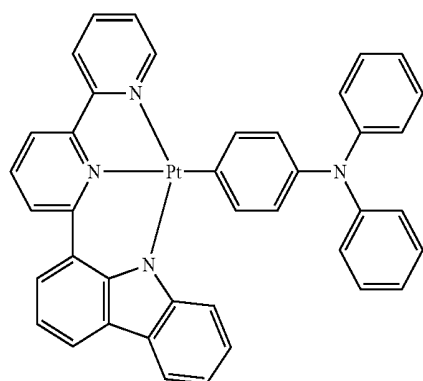


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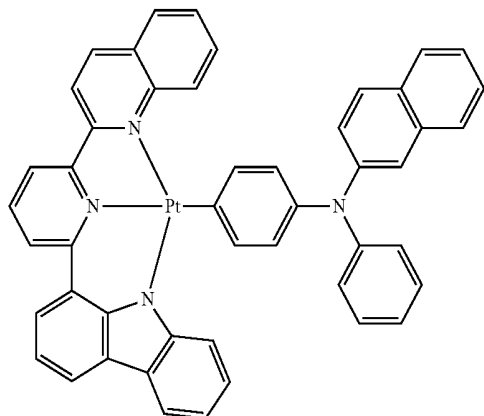
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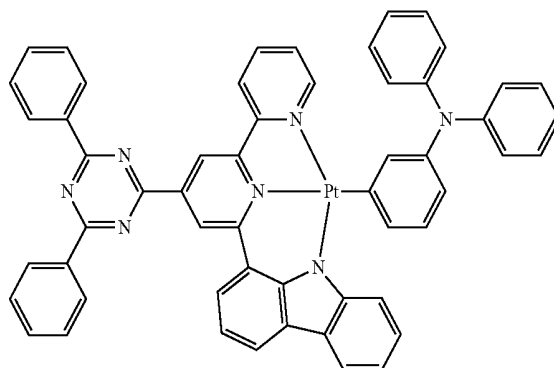
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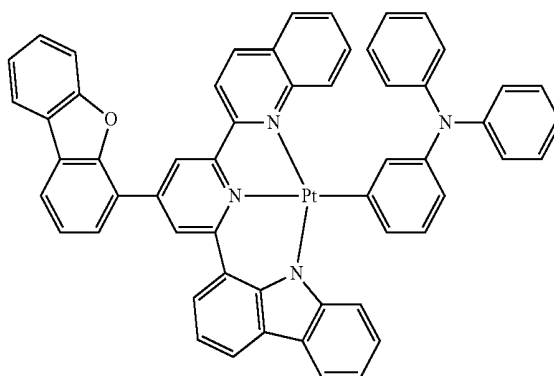


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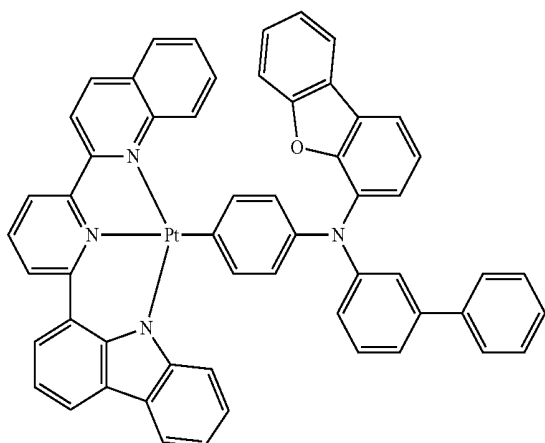
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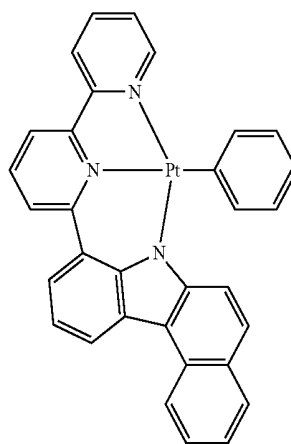
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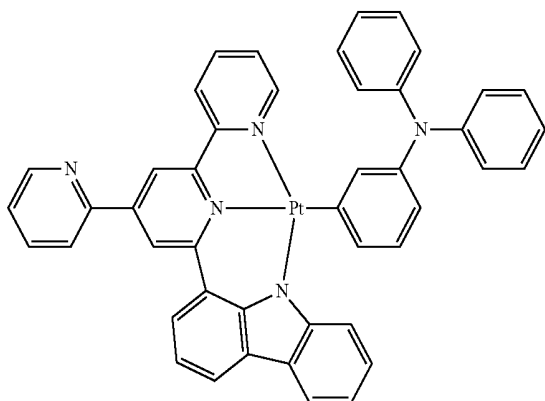
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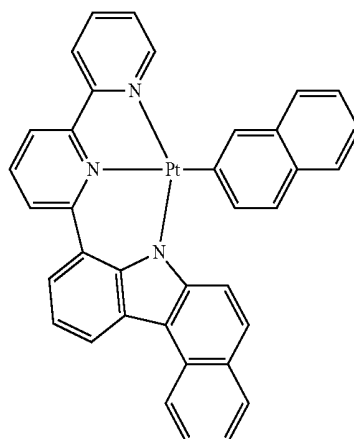
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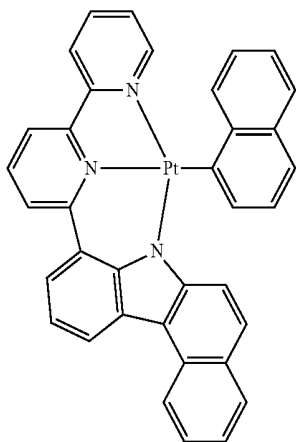
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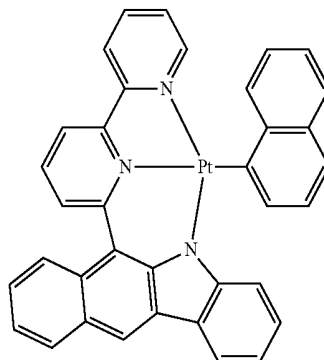


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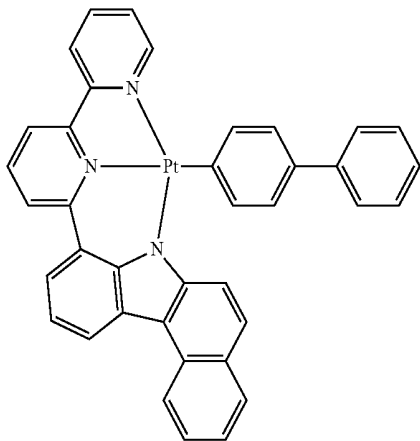


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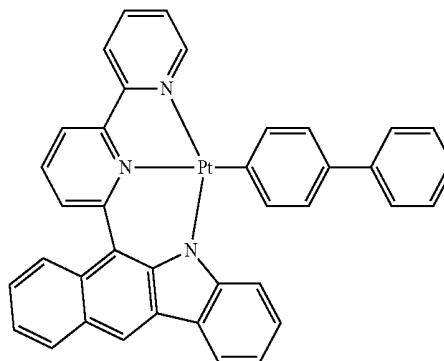
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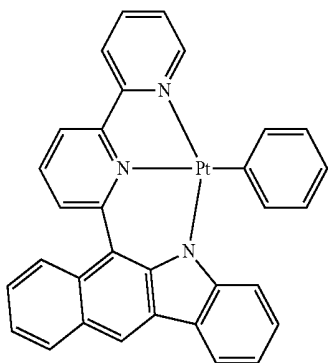
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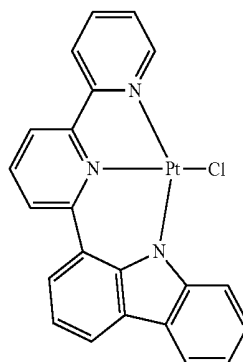
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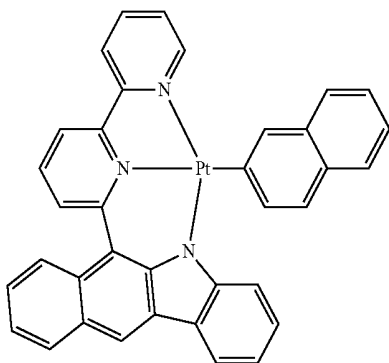
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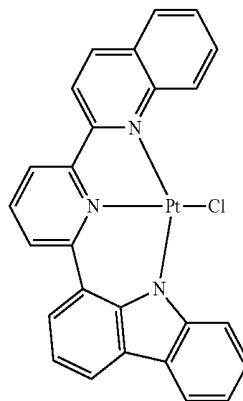
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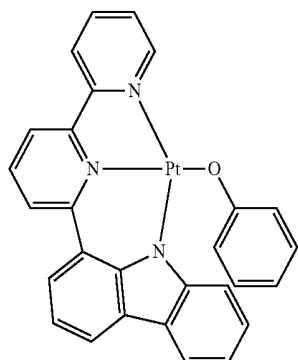


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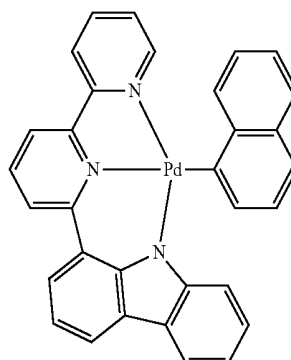
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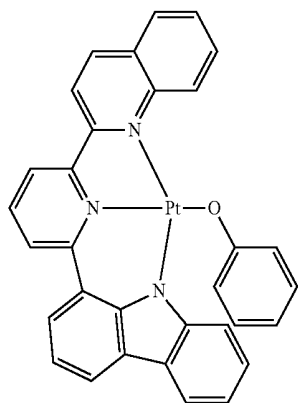


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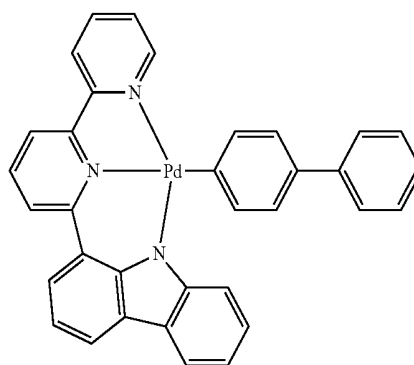
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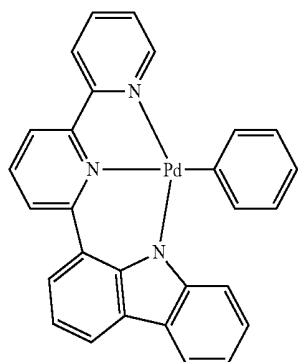
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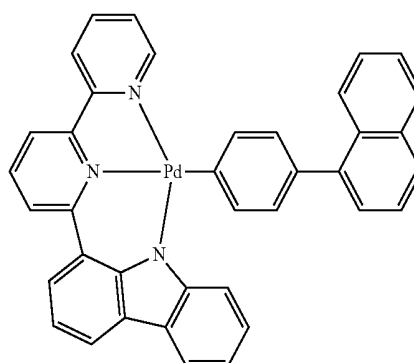
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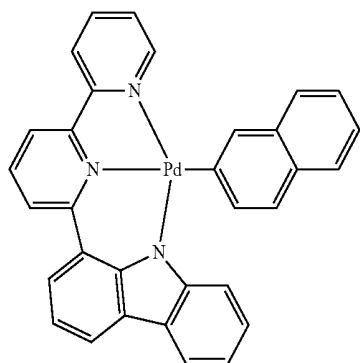
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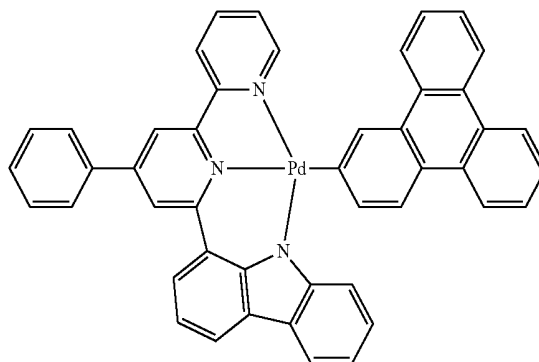
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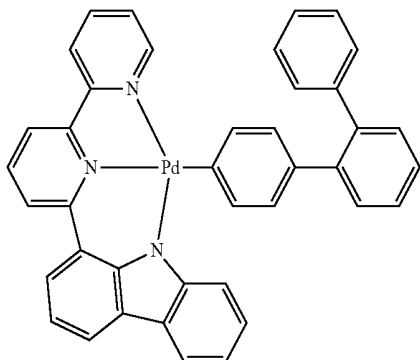
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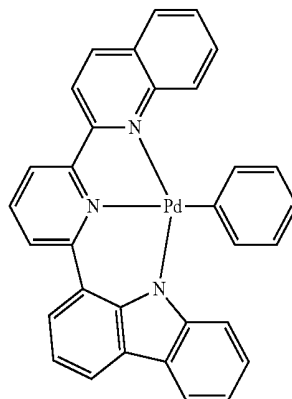
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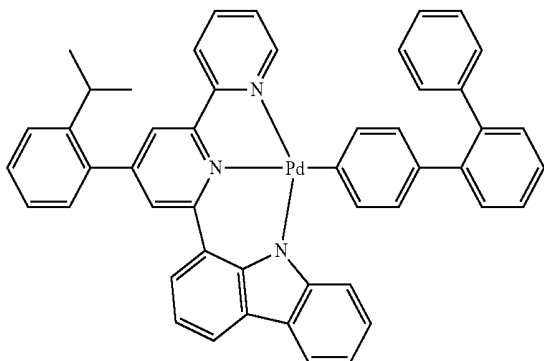


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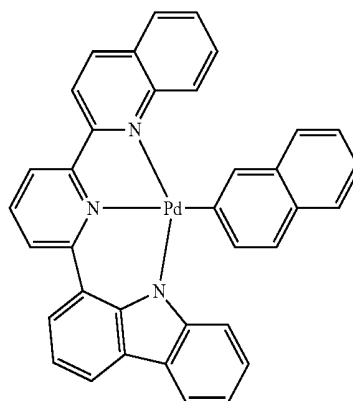
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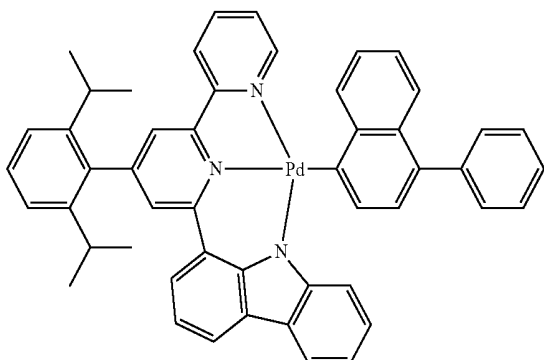
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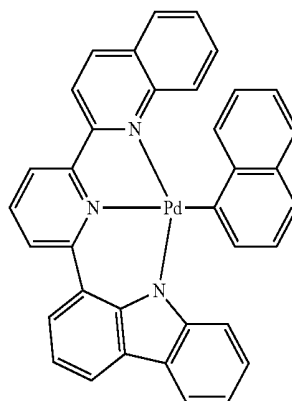
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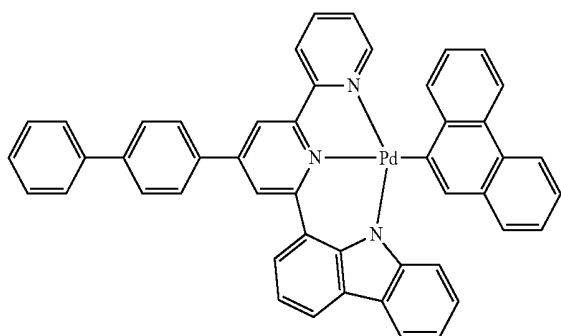
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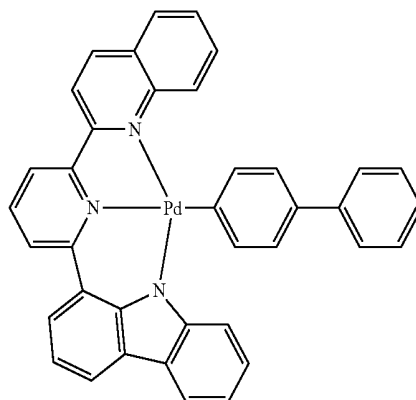
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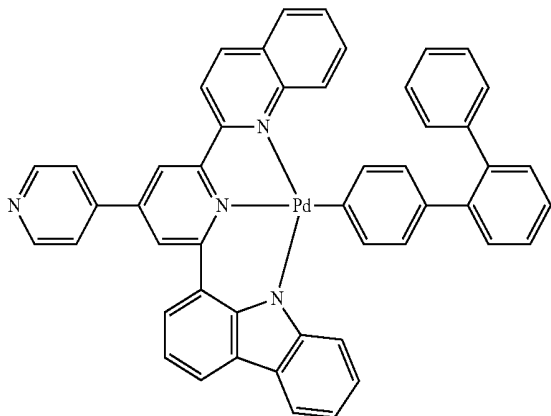


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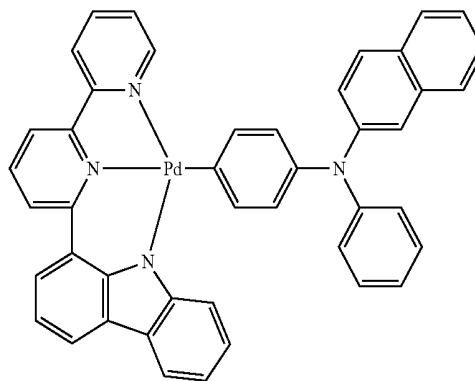
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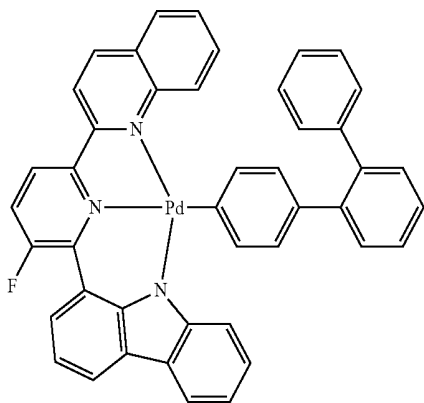


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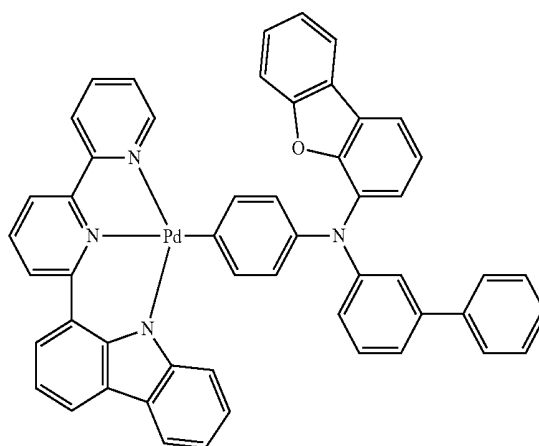
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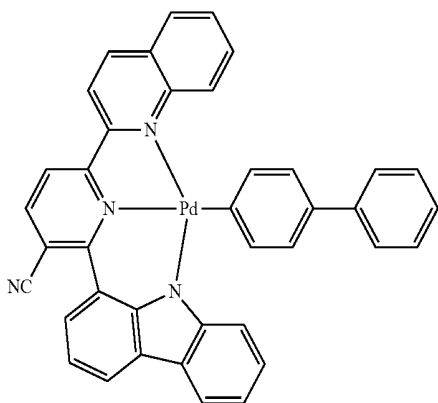
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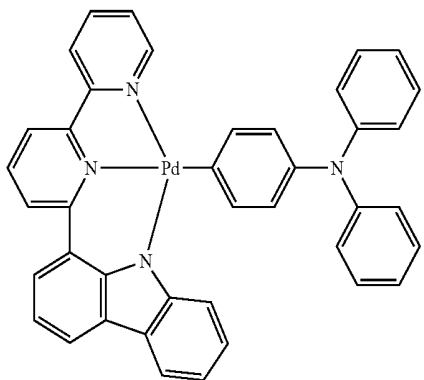
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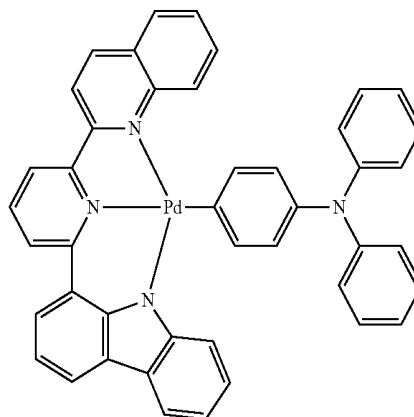
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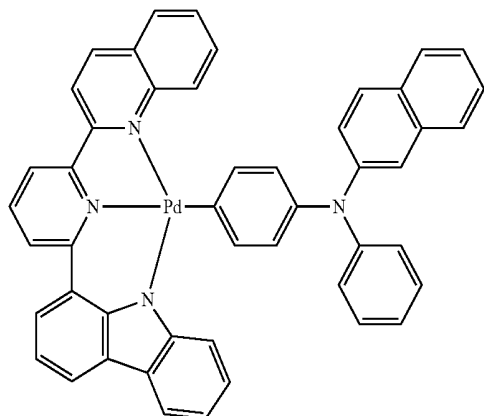


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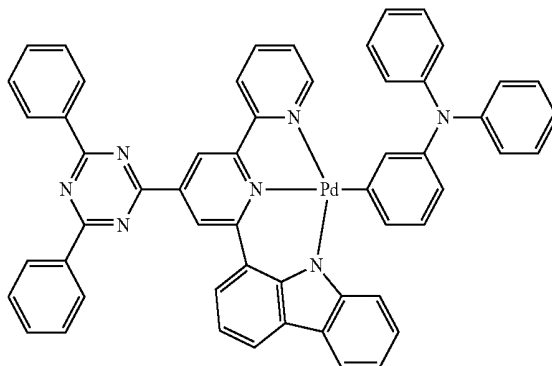
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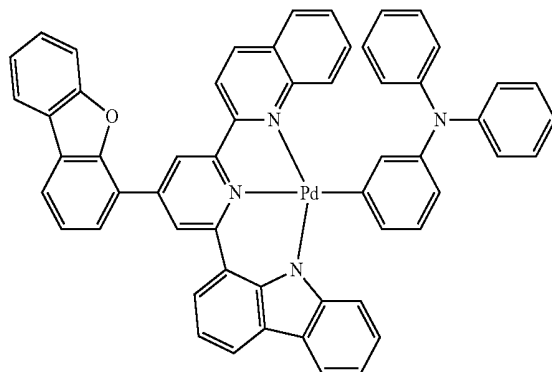


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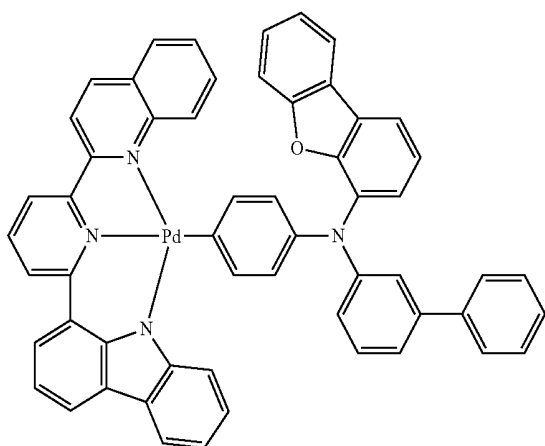
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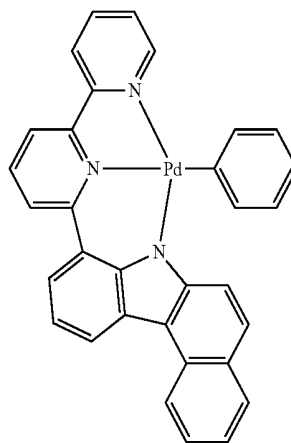
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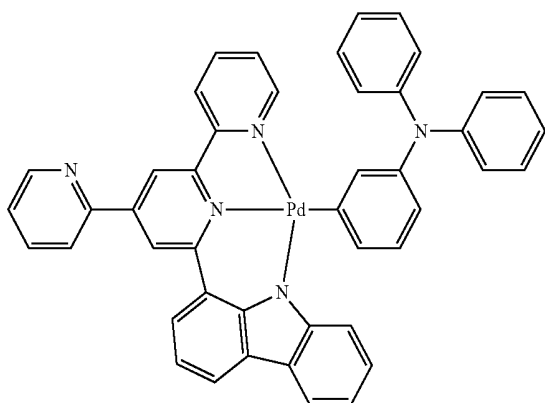
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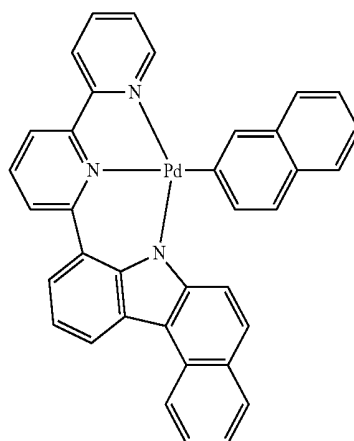
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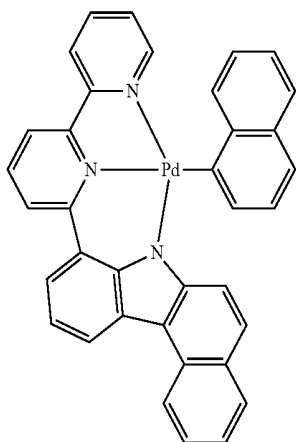
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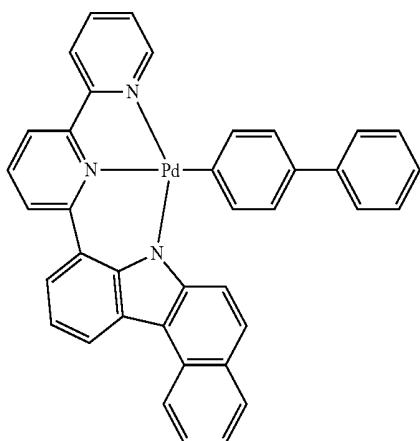
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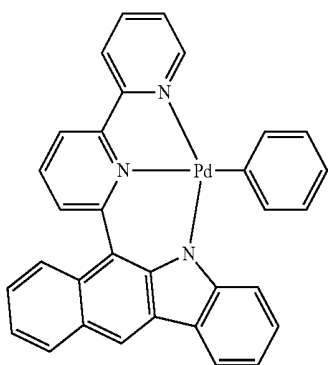
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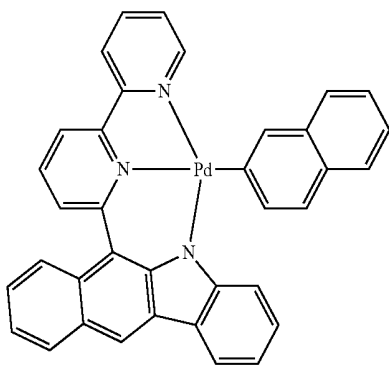
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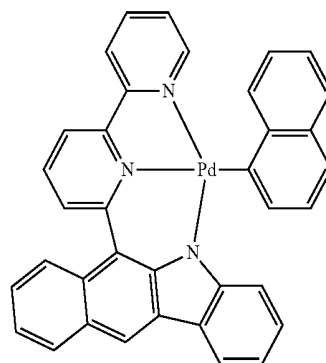


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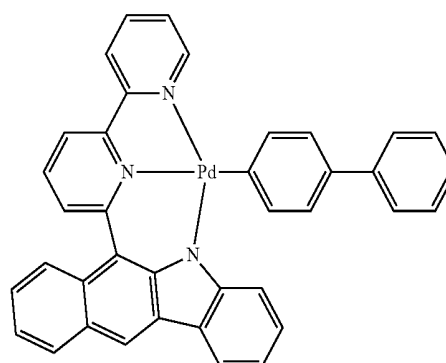


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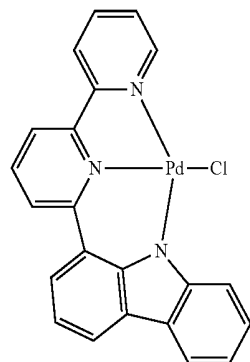
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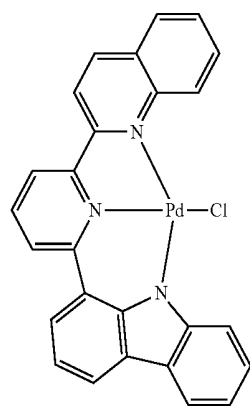
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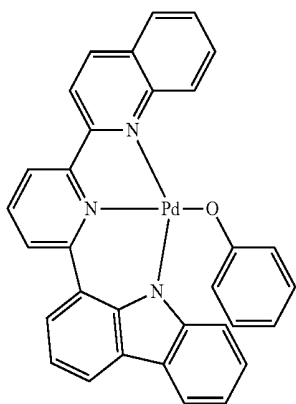
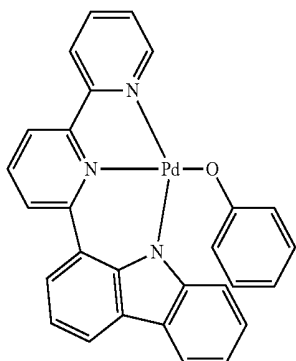


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14. An organic light-emitting device comprising:
a first electrode;
a second electrode facing the first electrode; and

75 an organic layer between the first electrode and the second electrode, the organic layer comprising an emission layer and at least one of the organometallic compound of claim 1.

15. The organic light-emitting device of claim 14, wherein the first electrode is an anode, the second electrode is a cathode, and the organic layer comprises i) a hole transport region between the first electrode and the emission layer, the hole transport region comprising a hole injection layer, a hole transport layer, a buffer layer, an electron blocking layer, or a combination thereof and ii) an electron transport region between the emission layer and the second electrode, the electron transport region comprising a hole blocking layer, an electron transport layer, an electron injection layer, or a combination thereof.

16. The organic light-emitting device of claim 14, wherein the emission layer comprises the at least one of organometallic compound.

17. The organic light-emitting device of claim 16, wherein the organometallic compound has a maximum emission wavelength in a range of about 700 nm to about 1,100 nm.

18. The organic light-emitting device of claim 16, wherein the emission layer further comprises a host, and an amount of the host is larger than an amount of the organometallic compound.

19. An apparatus comprising the organic light-emitting device of claim 14.

20. The apparatus of claim 19, wherein the apparatus is a light-emitting apparatus, an authentication apparatus, or an electronic apparatus.

* * * * *

专利名称(译)	有机金属化合物和包括其的有机发光器件		
公开(公告)号	US20190103566A1	公开(公告)日	2019-04-04
申请号	US15/921590	申请日	2018-03-14
[标]申请(专利权)人(译)	三星显示有限公司		
申请(专利权)人(译)	三星DISPLAY CO. , LTD.		
当前申请(专利权)人(译)	三星DISPLAY CO. , LTD.		
[标]发明人	KIM SEULONG KO SOOBYUNG KIM MYEONGSUK YE JIMYOUNG YOO BYEONGWOOK LEE HEUNSEUNG HWANG JAEHOON		
发明人	KIM, SEULONG KO, SOOBYUNG KIM, MYEONGSUK YE, JIMYOUNG YOO, BYEONGWOOK LEE, HEUNSEUNG HWANG, JAEHOON		
IPC分类号	H01L51/00 C07F15/00 C09K11/06		
CPC分类号	H01L51/0087 C07F15/0093 C09K11/06 H01L51/5024 H01L51/5088 H01L51/5056 H01L51/5096 H01L51/5072 H01L51/5092 H01L51/5004 H01L2251/552 C09K2211/185 C09K2211/1029		
优先权	1020170128295 2017-09-29 KR		
外部链接	Espacenet USPTO		

摘要(译)

提供有机金属化合物和包含其的有机发光装置。有机金属化合物由下式1表示：

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