

(19)



(11)

EP 3 889 162 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:

06.10.2021 Bulletin 2021/40

(51) Int Cl.:

C07F 15/00 (2006.01)

C09K 11/06 (2006.01)

H01L 51/00 (2006.01)

(21) Application number: **21159535.0**

(22) Date of filing: **26.02.2021**

(84) Designated Contracting States:

**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**

Designated Extension States:

BA ME

Designated Validation States:

KH MA MD TN

• **KO, Soobyung**

17113 Yongin-si (KR)

• **KIM, Haejin**

17113 Yongin-si (KR)

• **SHIN, Sujin**

17113 Yongin-si (KR)

• **LEE, Hyunjung**

17113 Yongin-si (KR)

• **HAN, Junghoon**

17113 Yongin-si (KR)

(30) Priority: **23.03.2020 KR 20200035140**

(71) Applicant: **Samsung Display Co., Ltd.**

Yongin-si, Gyeonggi-Do 17113 (KR)

(74) Representative: **Shearman, James Ward**

Marks & Clerk LLP

15 Fetter Lane

London EC4A 1BW (GB)

(72) Inventors:

• **AHN, Eunsoo**

17113 Yongin-si (KR)

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

(57) Provided are an organometallic compound represented by Formula 1 and an organic light-emitting device including the same. The organic light-emitting device includes: a first electrode, a second electrode, and an organic layer between the first electrode and the second electrode and including an emission layer, wherein the emission layer includes the organometallic compound.

FIG. 1

10

190

150

110

EP 3 889 162 A1

Description

BACKGROUND

1. Field

[0001] One or more embodiments of the present disclosure relate to an organometallic compound and an organic light-emitting device including the same.

2. Description of Related Art

[0002] Organic light-emitting devices (OLEDs) are self-emission devices that have wide viewing angles, high contrast ratios, short response times, and excellent characteristics in terms of brightness, driving voltage, and response speed, as compared to other devices in the art.

[0003] OLEDs may include a first electrode on a substrate, and a hole transport region, an emission layer, an electron transport region, and a second electrode sequentially stacked on the first electrode. Holes provided from the first electrode may move toward the emission layer through the hole transport region, and electrons provided from the second electrode may move toward the emission layer through the electron transport region. Carriers, such as holes and electrons, recombine in the emission layer to produce excitons. These excitons transit (e.g., transition or relax) from an excited state to a ground state to thereby generate light.

SUMMARY

[0004] One or more embodiments include an organometallic compound having a novel structure and an organic light-emitting device including the organometallic compound and having high luminescence efficiency and a long lifespan.

[0005] Additional aspects of embodiments 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 of the disclosure.

[0006] According to one or more embodiments, there is provided an organometallic compound represented by Formula 1



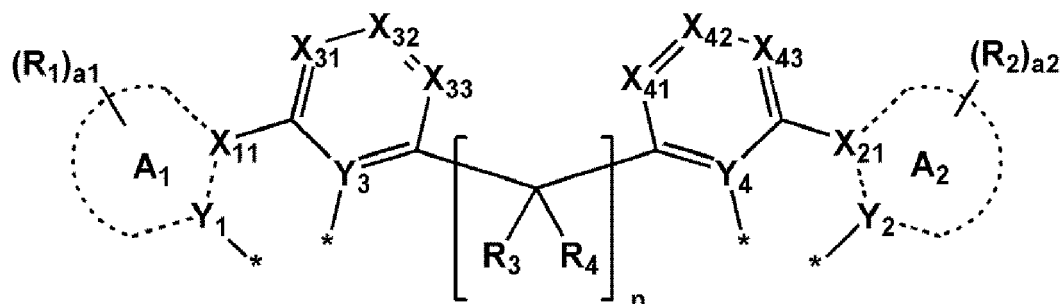
wherein, in Formula 1,

M is selected from iridium (Ir), cobalt (Co), rhodium (Rh), and meitnerium (Mt),

L_1 is a ligand represented by Formula 1-1, and

L_2 is a bidentate organic ligand,

Formula 1-1



wherein, in Formula 1-1, ring A_1 and ring A_2 are each independently selected from a C_5 - C_{30} carbocyclic group and a C_1 - C_{30} heterocyclic group,

Y_1 to Y_4 are each independently selected from N and C,

X_{11} and X_{21} are each independently selected from N and C,

X_{31} is C(R_{31}) or N, X_{32} is C(R_{32}) or N, X_{33} is C(R_{33}) or N, X_{41} is C(R_{41}) or N, X_{42} is C(R_{42}) or N, and X_{43} is C(R_{43}) or N, R_1 to R_4 , R_{31} to R_{33} , and R_{41} to R_{43} 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 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-C₁₈ cycloalkyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₈ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₇-C₆₀ alkylaryl 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 C₂-C₆₀ alkylheteroaryl group, a substituted or unsubstituted C₁-C₆₀ heteroaryloxy group, a substituted or unsubstituted C₁-C₆₀ heteroarylthio 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), a₁ and a₂ are each independently an integer from 1 to 10,

n is an integer from 2 to 6,

* indicates a binding site to the metal M,

at least one substituent of the substituted C₁-C₆₀ alkyl group, the substituted C₂-C₆₀ alkenyl group, the substituted C₂-C₆₀ alkynyl group, the substituted C₁-C₆₀ alkoxy group, the substituted C₃-C₁₈ cycloalkyl group, the substituted C₁-C₁₈ heterocycloalkyl group, the substituted C₃-C₁₈ cycloalkenyl group, the substituted C₁-C₁₈ heterocycloalkenyl group, the substituted C₆-C₆₀ aryl group, the substituted C₇-C₆₀ alkylaryl group, the substituted C₆-C₆₀ aryloxy group, the substituted C₆-C₆₀ arylthio group, the substituted C₁-C₆₀ heteroaryl group, the substituted C₂-C₆₀ alkylheteroaryl group, the substituted C₁-C₆₀ heteroaryloxy group, the substituted C₁-C₆₀ heteroarylthio 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-C₁₈ cycloalkyl group, a C₁-C₁₈ heterocycloalkyl group, a C₃-C₁₈ cycloalkenyl group, a C₁-C₁₈ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₇-C₆₀ alkylaryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a C₂-C₆₀ alkylheteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, -O(Q₁₁), -S(Q₁₁), -Si(Q₁₁)(Q₁₂)(Q₁₃), -N(Q₁₁)(Q₁₂), -B(Q₁₁)(Q₁₂), -C(=O)(Q₁₁), -S(=O)₂(Q₁₁), and -P(=O)(Q₁₁)(Q₁₂)

a C₃-C₁₈ cycloalkyl group, a C₁-C₁₈ heterocycloalkyl group, a C₃-C₁₈ cycloalkenyl group, a C₁-C₁₈ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₇-C₆₀ alkylaryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a C₂-C₆₀ alkylheteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

a C₃-C₁₈ cycloalkyl group, a C₁-C₁₈ heterocycloalkyl group, a C₃-C₁₈ cycloalkenyl group, a C₁-C₁₈ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₇-C₆₀ alkylaryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a C₂-C₆₀ alkylheteroaryl 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-C₁₈ cycloalkyl group, a C₁-C₁₈ heterocycloalkyl group, a C₃-C₁₈ cycloalkenyl group, a C₁-C₁₈ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₇-C₆₀ alkylaryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a C₂-C₆₀ alkylheteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, -O(Q₂₁), -S(Q₂₁), -Si(Q₂₁)(Q₂₂)(Q₂₃), -N(Q₂₁)(Q₂₂), -B(Q₂₁)(Q₂₂), -C(=O)(Q₂₁), -S(=O)₂(Q₂₁), and -P(=O)(Q₂₁)(Q₂₂), and

-O(Q₃₁), -S(Q₃₁), -Si(Q₃₁)(Q₃₂)(Q₃₃), -N(Q₃₁)(Q₃₂), -B(Q₃₁)(Q₃₂), -C(=O)(Q₃₁), -S(=O)₂(Q₃₁), and -P(=O)(Q₃₁)(Q₃₂), 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-C₁₈ 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 C₁-C₆₀ alkyl group that is substituted with at least one selected from deuterium, -F, a cyano group, a C₁-C₆₀ alkyl group, a phenyl group, a biphenyl group, and a terphenyl group, and a C₆-C₆₀ aryl group that is substituted with at least one selected from deuterium, -F, a cyano group, a C₁-C₁₈ alkyl group, a phenyl group, and a biphenyl group.

[0007] According to one or more embodiments, there is provided an organic light-emitting device including a first electrode, a second electrode, and an organic layer between the first electrode and the second electrode and including

an emission layer, wherein the emission layer includes the organometallic compound.

[0008] At least some of the above and other features of the invention are set out in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The above and other aspects and features of certain embodiments of the present disclosure will be more apparent from the following description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a schematic cross-sectional view of an organic light-emitting device according to an embodiment; FIG. 2 is a schematic cross-sectional view of an organic light-emitting device according to an embodiment; FIG. 3 is a schematic cross-sectional view of an organic light-emitting device according to an embodiment; and FIG. 4 is a schematic cross-sectional view of an organic light-emitting device according to an embodiment.

DETAILED DESCRIPTION

[0010] Reference will now be made in more detail to embodiments, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout. In this regard, the present embodiments may have different forms and should not be construed as being limited to the descriptions set forth herein. Accordingly, the embodiments are merely described below, by referring to the figures, to explain aspects of embodiments of the present description. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items. Throughout the disclosure, the expression "at least one of a, b or c" indicates only a, only b, only c, both a and b, both a and c, both b and c, all of a, b, and c, or variations thereof.

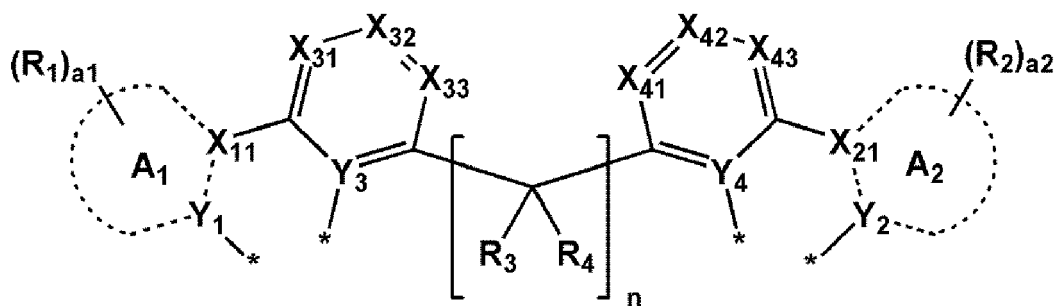
[0011] An aspect of an embodiment of the present disclosure provides an organometallic compound represented by Formula 1 below:



[0012] In Formula 1, M is selected from iridium (Ir), rhodium (Rh), cobalt (Co), and meitnerium (Mt). For example, M may be selected from iridium (Ir), rhodium (Rh), and cobalt (Co). For example, M may be Ir.

[0013] In Formula 1, L_1 is a ligand represented by Formula 1-1 below, and L_2 is a bidentate organic ligand:

Formula 1-1



[0014] In Formula 1-1, ring A_1 and ring A_2 are each independently selected from a C_5 - C_{38} carbocyclic group and a C_1 - C_{30} heterocyclic group. For example, ring A_1 and ring A_2 may each independently be selected from a C_5 - C_{20} carbocyclic group and a C_1 - C_{20} heterocyclic group.

[0015] In one embodiment, ring A_1 and ring A_2 may each independently be selected from i) a first ring, ii) a second ring, iii) a condensed ring in which two or more first rings are condensed with each other (e.g., combined together), iv) a condensed ring in which two or more second rings are condensed with each other (e.g., combined together), and v) a condensed ring in which one or more first rings and one or more second rings are condensed with each other (e.g., combined together),

the first ring may be selected from a cyclopentane group, a cyclopentene group, a cyclopentadiene group, a furan group, a thiophene group, a pyrrole group, a borole group, a phosphole group, a silole group, a germole group, a selenophene group, an oxazole group, an isoxazole group, an oxadiazole group, an isoxadiazole group, an oxatriazole group, an isoxatriazole group, a thiazole group, an isothiazole group, a thiadiazole group, an isothiadiazole group, a thiatriazole group, an isothiatriazole group, a pyrazole group, an imidazole group, a triazole group, a tetrazole group, an azasilole

group, a diazasilole group, and a triazasilole group, and

the second ring may be selected from a cyclohexane group, a cyclohexene group, a cyclohexadiene group, an adamantane group, a norbornane group, a norbornene group, a benzene group, a pyridine group, a dihydropyridine group, a tetrahydropyridine group, a pyrimidine group, a dihydropyrimidine group, a tetrahydropyrimidine group, a pyrazine group, a dihydropyrazine group, a tetrahydropyrazine group, a pyridazine group, a dihydropyridazine group, a tetrahydropyridazine group, a triazine group, an oxasilene group, a thiasilene group, a dihydroazasilene group, a dihydrodisilene group, a dihydrosilene group, a dioxine group, an oxathiine group, an oxazine group, a pyran group, a dithiine group, a thiazine group, and a thiopyran group.

[0016] For example, ring A₁ and ring A₂ may each independently be selected from a benzene group, a naphthalene group, an anthracene group, a phenanthrene group, a triphenylene group, a pyrene group, a chrysene group, a furan group, a thiophene group, a silole group, an indene group, a fluorene group, a benzofuran group, a dibenzofuran group, a benzothiophene group, a dibenzothiophene group, a benzosilole group, a dibenzosilole group, an indole group, a carbazole group, an indenopyridine group, an indolopyridine group, a benzofuropyridine group, a benzothienopyridine group, a benzosilolopyridine group, an indenopyrimidine group, an indolopyrimidine group, a benzofuropyrimidine group, a benzothienopyrimidine group, a benzosilolopyrimidine group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a triazine group, a quinoline group, an isoquinoline group, a quinoxaline group, a quinazoline group, a cinnoline group, a phthalazine group, a phenanthroline group, a pyrrole group, a pyrazole group, an imidazole group, a triazole group, an oxazole group, an isoxazole group, a thiazole group, an isothiazole group, an oxadiazole group, a thiadiazole group, a benzopyrazole group, a benzimidazole group, an imidazopyridine group, an imidazopyrimidine group, an imidazopyrazine group, a benzoxazole group, a benzothiazole group, a benzoxadiazole group and a benzothiadiazole group, but embodiments of the present disclosure are not limited thereto.

[0017] For example, ring A₁ and ring A₂ may each independently be selected from a benzene group, a naphthalene group, an indene group, a benzofuran group, a benzothiophene group, an indole group, a benzimidazole group, a benzoxazole group, a benzoisoxazole group, a benzothiazole group, a benzoisothiazole group, a quinoline group, an isoquinoline group, a quinoxaline group, a phthalazine group, a quinazoline group, and a cinnoline group, but embodiments of the present disclosure are not limited thereto.

[0018] For example, ring A₁ and ring A₂ may be identical to each other. For example, ring A₁ and ring A₂ may both be a benzene group. While ring A₁ and ring A₂ may be identical to each other, the substituents of ring A₁ and ring A₂ may be the same or different. For example, ring A₁ and ring A₂ may both be a benzene group having the same or different substituents as each other.

[0019] In Formula 1-1, Y₁ to Y₄ are each independently selected from N and C.

[0020] In one embodiment, two selected from Y₁ to Y₄ may each independently be N, and the other two may each independently be C.

[0021] For example, one selected from Y₁ and Y₃ may be N, and the other may be C, and one selected from Y₂ and Y₄ may be N, and the other may be C.

[0022] For example, Y₁ and Y₂ may each independently be C, Y₃ and Y₄ may each independently be N, a bond between M and each of Y₁ and Y₂ may be a covalent bond, and a bond between M and each of Y₃ and Y₄ may be a coordination bond.

[0023] In Formula 1-1, X₁₁ and X₂₁ are each independently selected from N and C.

[0024] In one embodiment, X₁₁ and X₂₁ may each independently be C, but embodiments of the present disclosure are not limited thereto.

[0025] In Formula 1-1, X₃₁ is C(R₃₁) or N, X₃₂ is C(R₃₂) or N, X₃₃ is C(R₃₃) or N, X₄₁ is C(R₄₁) or N, X₄₂ is C(R₄₂) or N, and X₄₃ is C(R₄₃) or N.

[0026] In one embodiment, X₃₁ may be C(R₃₁), X₃₂ may be C(R₃₂), X₃₃ may be C(R₃₃), X₄₁ may be C(R₄₁), X₄₂ may be C(R₄₂), and X₄₃ may be C(R₄₃).

[0027] In Formula 1-1, R₁ to R₄, R₃₁ to R₃₃, and R₄₁ to R₄₃ 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 C₁-C₆₀ (e.g. C₁-C₂₀) alkyl group, a substituted or unsubstituted C₂-C₆₀ (e.g. C₂-C₂₀) alkenyl group, a substituted or unsubstituted C₂-C₆₀ (e.g. C₂-C₂₀) alkynyl group, a substituted or unsubstituted C₁-C₆₀ (e.g. C₁-C₂₀) alkoxy group, a substituted or unsubstituted C₃-C₁₈ cycloalkyl group, a substituted or unsubstituted C₁-C₁₈ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₈ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₈ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ (e.g. C₆-C₃₀) aryl group, a substituted or unsubstituted C₇-C₆₀ (e.g. C₇-C₃₀) alkylaryl group, a substituted or unsubstituted C₆-C₆₀ (e.g. C₆-C₃₀) aryloxy group, a substituted or unsubstituted C₆-C₆₀ (e.g. C₆-C₃₀) arylthio group, a substituted or unsubstituted C₁-C₆₀ (e.g. C₁-C₂₀) heteroaryl group, a substituted or unsubstituted C₂-C₆₀ (e.g. C₂-C₂₀) alkylheteroaryl group, a substituted or unsubstituted C₁-C₆₀ (e.g. C₁-C₂₀) heteroaryloxy group, a substituted or unsubstituted C₁-C₆₀ (e.g. C₁-C₂₀) heteroarylthio 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)(O₁)(O₂).

[0028] In one embodiment, R₁ to R₄, R₃₁ to R₃₃, and R₄₁ to R₄₃ 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 (e.g. C₁-C₂₀) alkyl group, and a C₁-C₆₀ (e.g. C₁-C₂₀) alkoxy group; a C₁-C₆₀ (e.g. C₁-C₂₀) alkyl group and a C₁-C₆₀ (e.g. C₁-C₂₀) alkoxy group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, -CD₃, -CD₂H, -CDH₂, -CF₃, -CF₂H, -CFH₂, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a biphenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group;

a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl 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 perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl 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 benzoquinolinyl group, a benzoisoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, a benzoisothiazolyl group, a benzoxazolyl group, a benzoisoxazolyl group, a triazolyl group, a tetrazolyl group, a thiadiazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphtho silolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafluorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indeno carbazolyl group, and an indolocarbazolyl group;

a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl 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 perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl 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 benzoquinolinyl group, a benzoisoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, a benzoisothiazolyl group, a benzoxazolyl group, a benzoisoxazolyl group, a triazolyl group, a tetrazolyl group, a thiadiazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphtho silolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafluorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indeno carbazolyl group, and an indolocarbazolyl group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, -CD₃, -CD₂H, -CDH₂, -CF₃, -CF₂H, -CFH₂, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₁-C₆₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl 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 perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl 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 benzoquinolinyl group, a benzoisoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, a benzoisothiazolyl group, a benzoxazolyl group, a benzoisoxazolyl group, a triazolyl group, a tetrazolyl group, a thiadiazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphtho silolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafuorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indeno carbazolyl group, an indolocarbazolyl 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 $-\text{Si}(\text{Q}_1)(\text{Q}_2)(\text{Q}_3)$, $-\text{N}(\text{Q}_1)(\text{Q}_2)$, $-\text{B}(\text{Q}_1)(\text{Q}_2)$, $-\text{C}(=\text{O})(\text{Q}_1)$, $-\text{S}(=\text{O})_2(\text{Q}_1)$, and $-\text{P}(=\text{O})(\text{Q}_1)(\text{Q}_2)$, and Q_1 to Q_3 and Q_{31} to Q_{33} may each independently be selected from hydrogen, deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a $\text{C}_1\text{-C}_{60}$ (e.g. $\text{C}_1\text{-C}_{20}$) alkyl group, a $\text{C}_2\text{-C}_{60}$ (e.g. $\text{C}_2\text{-C}_{20}$) alkenyl group, a $\text{C}_2\text{-C}_{60}$ (e.g. $\text{C}_2\text{-C}_{20}$) alkynyl group, a $\text{C}_1\text{-C}_{60}$ (e.g. $\text{C}_1\text{-C}_{20}$) alkoxy group, a $\text{C}_3\text{-C}_{18}$ cycloalkyl group, a $\text{C}_1\text{-C}_{18}$ heterocycloalkyl group, a $\text{C}_3\text{-C}_{18}$ cycloalkenyl group, a $\text{C}_1\text{-C}_{18}$ heterocycloalkenyl group, a $\text{C}_6\text{-C}_{60}$ (e.g. $\text{C}_6\text{-C}_{30}$) aryl group, a $\text{C}_6\text{-C}_{60}$ (e.g. $\text{C}_6\text{-C}_{30}$) aryloxy group, a $\text{C}_6\text{-C}_{60}$ (e.g. $\text{C}_6\text{-C}_{30}$) arylthio group, a $\text{C}_1\text{-C}_{60}$ (e.g. $\text{C}_1\text{-C}_{20}$) heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a $\text{C}_1\text{-C}_{60}$ (e.g. $\text{C}_1\text{-C}_{20}$) alkyl group that is substituted with at least one selected from deuterium, -F, a cyano group, a $\text{C}_1\text{-C}_{60}$ (e.g. $\text{C}_1\text{-C}_{20}$) alkyl group, a phenyl group, and a biphenyl group, a $\text{C}_6\text{-C}_{60}$ (e.g. $\text{C}_6\text{-C}_{30}$) aryl group that is substituted with at least one selected from deuterium, -F, a cyano group, a $\text{C}_1\text{-C}_{18}$ alkyl group, a phenyl group, and a biphenyl group, and a $\text{C}_1\text{-C}_{60}$ (e.g. $\text{C}_1\text{-C}_{20}$) heteroaryl group that is substituted with at least one selected from deuterium, -F, a cyano group, a $\text{C}_1\text{-C}_{18}$ alkyl group, a phenyl group, and a biphenyl group.

[0029] For example, R_1 and R_2 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 methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, a tert-pentyl group, a neo-pentyl group, an isopentyl group, a sec-pentyl group, a 3-pentyl group, a sec-isopentyl group, an n-hexyl group, an isohexyl group, a sec-hexyl group, a tert-hexyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a biphenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group; and a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, a tert-pentyl group, a neo-pentyl group, an isopentyl group, a sec-pentyl group, a 3-pentyl group, a sec-isopentyl group, an n-hexyl group, an isohexyl group, a sec-hexyl group, a tert-hexyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a biphenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, $-\text{CD}_3$, $-\text{CD}_2\text{H}$, $-\text{CDH}_2$, $-\text{CF}_3$, $-\text{CF}_2\text{H}$, $-\text{CFH}_2$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a biphenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group, but embodiments of the present disclosure are not limited thereto.

[0030] For example, R_3 and R_4 may each independently be selected from:

hydrogen, deuterium, -F, -Cl, -Br, -I, a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-

butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, a tert-pentyl group, a neo-pentyl group, an isopentyl group, a sec-pentyl group, a 3-pentyl group, a sec-isopentyl group, an n-hexyl group, an isohexyl group, a sec-hexyl group, and a tert-hexyl group; and

a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, a tert-pentyl group, a neo-pentyl group, an isopentyl group, a sec-pentyl group, a 3-pentyl group, a sec-isopentyl group, an n-hexyl group, an isohexyl group, a sec-hexyl group, and a tert-hexyl group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, and -I, but embodiments of the present disclosure are not limited thereto.

[0031] For example, R_{31} to R_{33} and R_{41} to R_{43} 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 methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, a tert-pentyl group, a neo-pentyl group, an isopentyl group, a sec-pentyl group, a 3-pentyl group, a sec-isopentyl group, an n-hexyl group, an isohexyl group, a sec-hexyl group, and a tert-hexyl group;

a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, a tert-pentyl group, a neo-pentyl group, an isopentyl group, a sec-pentyl group, a 3-pentyl group, a sec-isopentyl group, an n-hexyl group, an isohexyl group, and a tert-hexyl group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, $-CD_3$, $-CD_2H$, $-CDH_2$, $-CF_3$, $-CF_2H$, $-CFH_2$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cycloheptenyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a biphenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group;

a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl 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 perylenyl group, a pentacenyl group, a pyridinyl group, and a pyrimidinyl group;

a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl 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 perylenyl group, a pentacenyl group, a pyridinyl group, and a pyrimidinyl group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, $-CD_3$, $-CD_2H$, $-CDH_2$, $-CF_3$, $-CF_2H$, $-CFH_2$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, a tert-pentyl group, a neo-pentyl group, an isopentyl group, a sec-pentyl group, a 3-pentyl group, a sec-isopentyl group, an n-hexyl group, an isohexyl group, a sec-hexyl group, a tert-hexyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl 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 perylenyl group, a pentacenyl group, a pyridinyl group, and a pyrimidinyl group, but embodiments of the present disclosure are not limited thereto.

[0032] In Formula 1-1, a_1 and a_2 are each independently an integer from 1 to 10, wherein, when a_1 is 2 or more, two or more $R_1(s)$ may be identical to each other or different from each other, and when a_2 is 2 or more, two or more $R_2(s)$ may be identical to or different from each other.

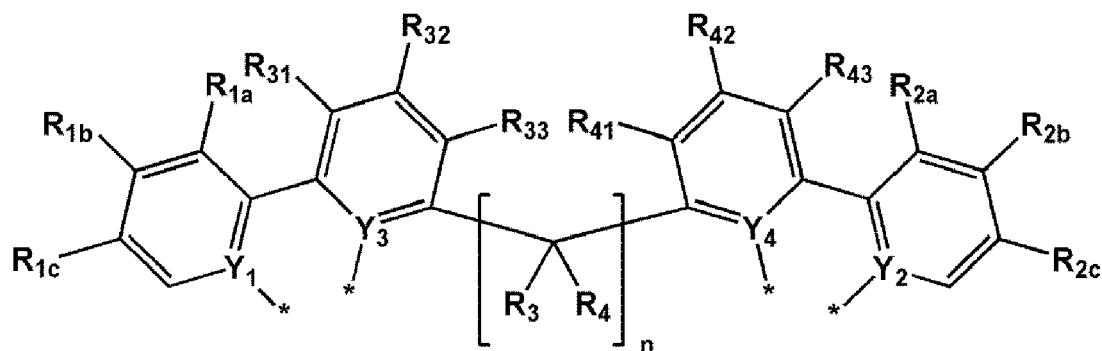
[0033] In Formula 1-1, n is an integer from 2 to 6.

[0034] In one embodiment, n may be an integer from 3 to 6 or an integer from 4 to 6.

[0035] * indicates a binding site to metal M,

[0036] In one embodiment, L_1 may be a ligand represented by Formula 1-1A below:

Formula 1-1A



[0037] In Formula 1-1A,

Y_1 , Y_2 , Y_3 , Y_4 , n , R_3 , R_4 , R_{31} , R_{32} , R_{33} , R_{41} , R_{42} , and R_{43} are each the same as described above, and R_{1a} , R_{1b} , and R_{1c} are each independently the same as described in connection with R_1 . Additionally, R_{2a} , R_{2b} , and R_{2c} are each independently the same as described in connection with R_2 , and R_{32} and R_{42} are each independently the same as described above and are identical to each other.

[0038] In one embodiment, R_{31} , R_{33} , R_{41} , and R_{43} in Formula 1-1 A may each be hydrogen.

[0039] In one embodiment, R_{1a} , R_{1c} , R_{2a} , and R_{2c} in Formula 1-1A may each independently be selected from:

hydrogen, deuterium, -F, -Cl, -Br, -I, a cyano group, and a C_1 - C_{18} alkyl group;

a C_1 - C_{18} alkyl group substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, - CD_3 , - CD_2H , - CDH_2 , - CF_3 , - CF_2H , - CFH_2 , and a cyano group;

a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, and a biphenyl group; and

a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, and a biphenyl group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, - CD_3 , - CD_2H , - CDH_2 , - CF_3 , - CF_2H , - CFH_2 , a cyano group, a C_1 - C_{18} alkyl group, a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, and a biphenyl group, but embodiments of the present disclosure are not limited thereto.

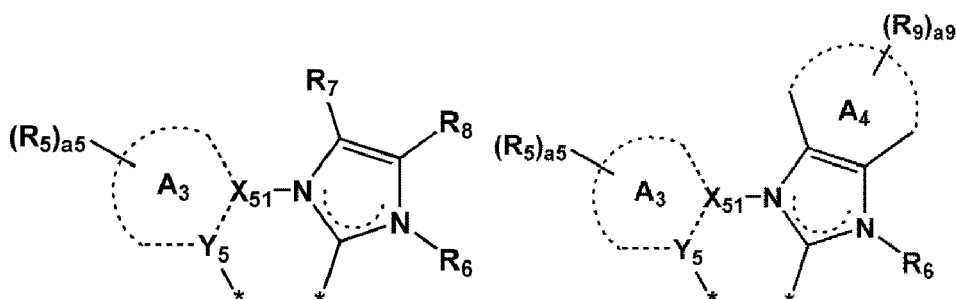
[0040] For example, R_{1a} and R_{2a} may be identical to each other, and R_{1c} and R_{2c} may be different from each other. For example, R_{1a} and R_{1c} may be identical to each other, and R_{2a} and R_{2c} may be different from each other.

[0041] In one embodiment, R_{1b} and R_{2b} in Formula 1-1 A may each be hydrogen.

[0042] In one embodiment, L_2 in Formula 1 may be a ligand represented by Formula 1-2A or 1-2B below:

Formula 1-2A

Formula 1-2B



[0043] In Formulae 1-2A and 1-2B,

A_3 and A_4 are each independently selected from a C_5 - C_{30} (e.g. C_5 - C_{20}) carbocyclic group and a C_1 - C_{30} (e.g. C_1 - C_{20}) heterocyclic group,

Y_5 is C or N,

X₅₁ is C or N,

R₅, R₆, R₇, R₈, and R₉ 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 C₁-C₆₀ (e.g. C₁-C₂₀) alkyl group, a substituted or unsubstituted C₂-C₆₀ (e.g. C₂-C₂₀) alkenyl group, a substituted or unsubstituted C₂-C₆₀ (e.g. C₂-C₂₀) alkynyl group, a substituted or unsubstituted C₁-C₆₀ (e.g. C₁-C₂₀) alkoxy group, a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₁-C₁₈ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₈ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ (e.g. C₆-C₃₀) aryl group, a substituted or unsubstituted C₇-C₆₀ (e.g. C₇-C₃₀) alkylaryl group, a substituted or unsubstituted C₆-C₆₀ (e.g. C₆-C₃₀) aryloxy group, a substituted or unsubstituted C₆-C₆₀ (e.g. C₆-C₃₀) arylthio group, a substituted or unsubstituted C₁-C₆₀ (e.g. C₁-C₂₀) heteroaryl group, a substituted or unsubstituted C₂-C₆₀ (e.g. C₂-C₂₀) alkylheteroaryl group, a substituted or unsubstituted C₁-C₆₀ (e.g. C₁-C₂₀) heteroaryloxy group, a substituted or unsubstituted C₁-C₆₀ (e.g. C₁-C₂₀) heteroarylthio group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropoly-cyclic group, -Si(Q₁)(Q₂)(Q₃), -N(Q₁)(Q₂), -B(Q₁)(Q₂), -C(=O)(Q₁), -S(=O)₂(Q₁), and -P(=O)(Q₁)(Q₂),

a₅ is an integer from 0 to 10, and

a₉ is an integer from 1 to 10.

[0044] In one embodiment, in Formulae 1-2A and 1-2B, ring A₃ and A₄ may each independently be selected from i) a first ring, ii) a second ring, iii) a condensed ring in which two or more first rings are condensed with each other (e.g., combined together), iv) a condensed ring in which two or more second rings are condensed with each other (e.g., combined together), and v) a condensed ring in which one or more first rings and one or more second rings are condensed with each other (e.g., combined together),

the first ring may be selected from a cyclopentane group, a cyclopentene group, a cyclopentadiene group, a furan group, a thiophene group, a pyrrole group, a borole group, a phosphole group, a silole group, a germole group, a selenophene group, an oxazole group, an isoxazole group, an oxadiazole group, an isoxadiazole group, an oxatriazole group, an isoxatriazole group, a thiazole group, an isothiazole group, a thiadiazole group, an isothiadiadiazole group, a thiatriazole group, an isothiatriazole group, a pyrazole group, an imidazole group, a triazole group, a tetrazole group, an azasilole group, a diazasilole group, and a triazasilole group, and

the second ring may be selected from a cyclohexane group, a cyclohexene group, a cyclohexadiene group, an adamantane group, a norbornane group, a norbornene group, a benzene group, a pyridine group, a dihydropyridine group, a tetrahydropyridine group, a pyrimidine group, a dihydropyrimidine group, a tetrahydropyrimidine group, a pyrazine group, a dihydropyrazine group, a tetrahydropyrazine group, a pyridazine group, a dihydropyridazine group, a tetrahydropyridazine group, a triazine group, an oxasiline group, a thiasiline group, a dihydroazasiline group, a dihydrodisilane group, a dihydrosilane group, a dioxine group, an oxathiine group, an oxazine group, a pyran group, a dithiine group, a thiazine group, and a thiopyran group, but embodiments of the present disclosure are not limited thereto.

[0045] For example, ring A₃ and ring A₄ may each independently be selected from a benzene group, a naphthalene group, an indene group, a benzofuran group, a benzothiophene group, an indole group, a benzimidazole group, a benzoxazole group, a benzoisoxazole group, a benzothiazole group, a benzoisothiazole group, a quinoline group, an isoquinoline group, a quinoxaline group, a phthalazine group, a quinoxaline group, a cinnoline group, a pyridine group, a pyrimidine group, and a pyrazine group, but embodiments of the present disclosure are not limited thereto.

[0046] In one embodiment, X₅₁ and Y₅ in Formulae 1-2A and 1-2B may each be C.

[0047] In one embodiment, R₅, R₆, R₇, R₈, and R₉ in Formulae 1-2A and 1-2B 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 (e.g. C₁-C₂₀) alkyl group, and a C₁-C₆₀ (e.g. C₁-C₂₀) alkoxy group; a C₁-C₆₀ (e.g. C₁-C₂₀) alkyl group and a C₁-C₆₀ (e.g. C₁-C₂₀) alkoxy group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, -CD₃, -CD₂H, -CDH₂, -CF₃, -CF₂H, -CFH₂, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a pyridinyl group, and a pyrimidinyl group; a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl 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 perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl 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 benzoquinolinyl

group, a benzoisoquinoliny group, a phthalazinyl group, a naphthyridinyl group, a quinoxaliny group, a benzoquinoxaliny group, a quinazoliny group, a benzoquinazoliny group, a cinnoliny group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, a benzoisothiazolyl group, a benzoxazolyl group, a benzoisoxazolyl group, a triazolyl group, a tetrazolyl group, a thiadiazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphtho silolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafluorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indeno carbazolyl group, and an indolocarbazolyl group;

a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl 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 perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl 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, a purinyl group, a quinoliny group, a quinoliny group, an isoquinoliny group, a benzoquinoliny group, a benzoisoquinoliny group, a phthalazinyl group, a naphthyridinyl group, a quinoxaliny group, a benzoquinoxaliny group, a quinazoliny group, a benzoquinazoliny group, a cinnoliny group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, a benzoisothiazolyl group, a benzoxazolyl group, a benzoisoxazolyl group, a triazolyl group, a tetrazolyl group, a thiadiazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphtho silolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafluorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indeno carbazolyl group, and an indolocarbazolyl group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, -CD₃, -CD₂H, -CDH₂, -CF₃, -CF₂H, -CFH₂, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ (e.g. C₁-C₂₀) alkyl group, a C₁-C₆₀ (e.g. C₁-C₂₀) alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl 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 perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl 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 quinoliny group, an isoquinoliny group, a benzoquinoliny group, a benzoisoquinoliny group, a phthalazinyl group, a naphthyridinyl group, a quinoxaliny group, a benzoquinoxaliny group, a quinazoliny group, a benzoquinazoliny group, a cinnoliny group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, a benzoisothiazolyl group, a benzoxazolyl group, a benzoisoxazolyl group, a triazolyl group, a tetrazolyl group, a thiadiazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphtho silolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafluorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indeno carbazolyl group, an indolocarbazolyl group, -Si(Q₃₁)(Q₃₂)(Q₃₃), -N(Q₃₁)(Q₃₂), -B(Q₃₁)(Q₃₂), -C(=O)(Q₃₁), -S(=O)₂(Q₃₁), and -P(=O)(O₃₁)(O₃₂); and -Si(Q₁)(Q₂)(Q₃), -N(Q₁)(Q₂), -B(Q₁)(Q₂), -C(=O)(Q₁), -S(=O)₂(Q₁), and -P(=O)(Q₁)(Q₂), and

Q₁ to Q₃ 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 (e.g. C₁-C₂₀) alkyl group, a C₂-C₆₀ (e.g. C₂-C₂₀) alkenyl group, a C₂-C₆₀ (e.g. C₂-C₂₀) alkynyl group, a C₁-C₆₀ (e.g. C₁-C₂₀) alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₈ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₈ heterocycloalkenyl group, a C₆-C₆₀ (e.g. C₆-C₃₀) aryl group, a C₆-C₆₀ (e.g. C₆-C₃₀) aryloxy group, a C₆-C₆₀ (e.g. C₆-C₃₀) arylthio group, a C₁-C₆₀ (e.g. C₁-C₂₀) heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a C₁-C₆₀ (e.g. C₁-C₂₀) alkyl group that is substituted with at least one selected from deuterium, -F, a cyano group, a C₁-C₆₀ (e.g. C₁-C₂₀) alkyl group, a phenyl group, and a biphenyl group, a C₆-C₆₀ aryl group that is substituted with at least one selected from deuterium, -F, a cyano group, a C₁-C₁₈ alkyl group, a phenyl group, and a biphenyl group, and a C₁-C₆₀ (e.g. C₁-C₂₀) heteroaryl group that is substituted with at least one selected from deuterium, -F, a cyano group, a C₁-C₁₈ alkyl group, a phenyl group, and a biphenyl group, but embodiments of the present disclosure are not limited thereto.

[0048] For example, R₅, R₆, R₇, R₈, and R₉ in Formulae 1-2A and 1-2B may each independently be selected from:

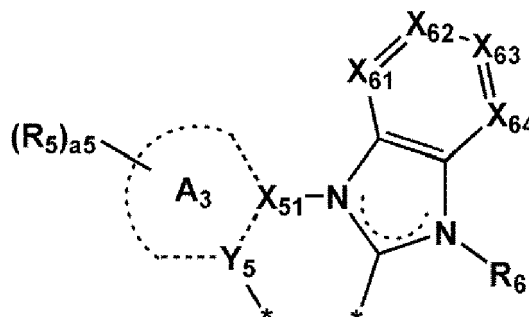
hydrogen, deuterium, -F, -Cl, -Br, -I, a cyano group, a C₁-C₁₈ alkyl group, and a C₁-C₁₈ alkoxy group; and a C₁-C₁₈ alkyl group and a C₁-C₁₈ alkoxy group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, -CD₃, -CD₂H, -CDH₂, -CF₃, -CF₂H, -CFH₂, a cyano group, a phenyl group, a biphenyl group, and a terphenyl group, but embodiments of the present disclosure are not limited thereto.

[0049] For example, R₅, R₆, R₇, R₈, and R₉ in Formulae 1-2A and 1-2B may each independently be selected from:

hydrogen, deuterium, -F, cyano group, a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, and a tert-butyl group; and a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, and a tert-butyl group, each substituted with at least one selected from deuterium, -F, and a cyano group, but embodiments of the present disclosure are not limited thereto.

[0050] In one embodiment, L₂ represented by Formula 1-2B may be a ligand represented by Formula 1-2B-1 below:

Formula 1-2B-1

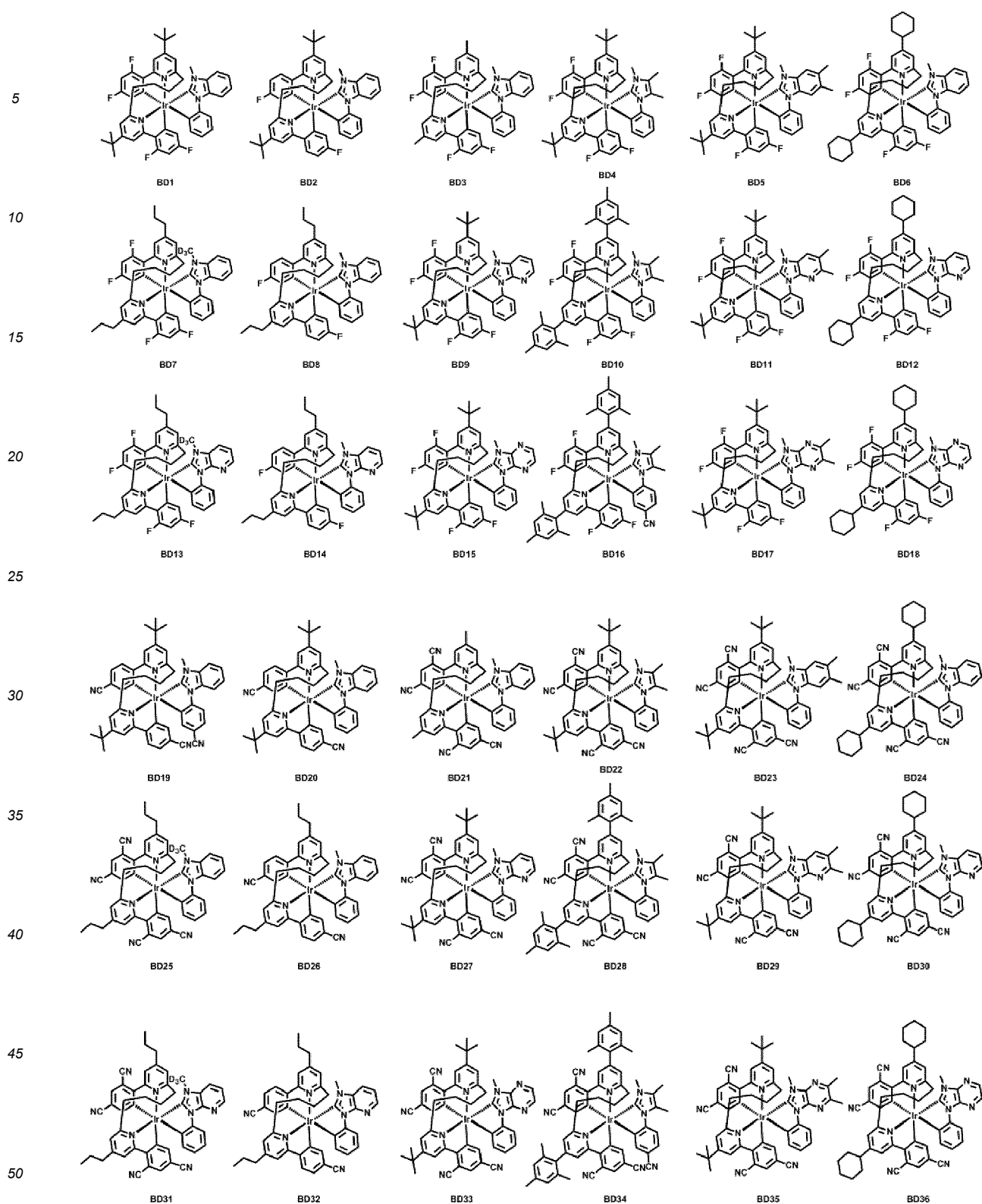


[0051] In Formula 1-2B-1, A₃, X₅₁, Y₅, R₅, R₆, and a₅ are each the same as described above,

X₆₁ is C(R₆₁) or N, X₆₂ is C(R₆₂) or N, X₆₃ is C(R₆₃) or N, X₆₄ is C(R₆₄) or N, and

R₆₁, R₆₂, R₆₃, and R₆₄ are each independently the same as described in connection with R₉.

[0052] In one embodiment, the organometallic compound represented by Formula 1 may be selected from Compounds BD1 to BD36 below:



[0053] Another aspect of an embodiment of the present disclosure provides an organic light-emitting device including: a first electrode; a second electrode; and an organic layer between the first electrode and the second electrode and including an emission layer, wherein the organic layer includes the organometallic compound.

[0054] In one embodiment, the emission layer may include the organometallic compound.

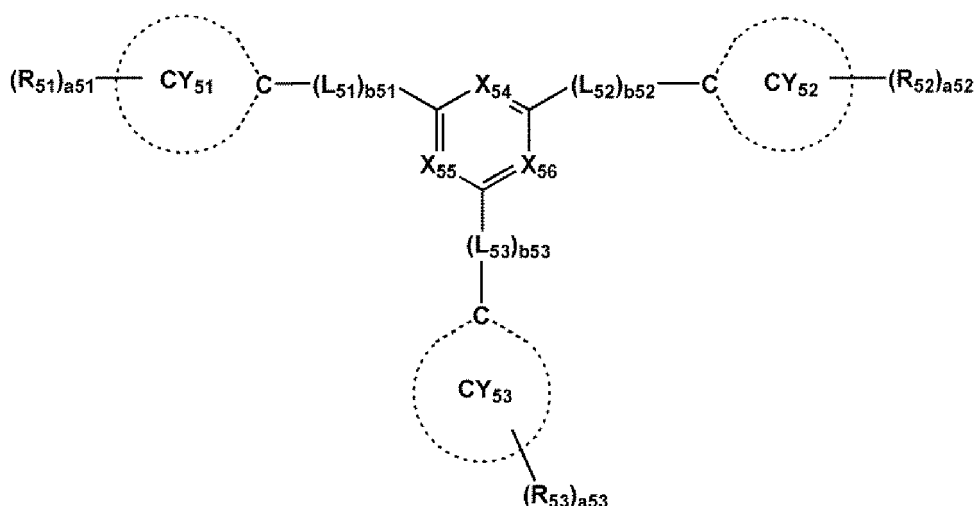
[0055] In one embodiment, the emission layer may further include a second compound and a third compound, wherein

the organometallic compound, the second compound, and the third compound are different from each other, the second compound and the third compound form an exciplex, and the organometallic compound and at least one of the second compound and the third compound may not form an exciplex.

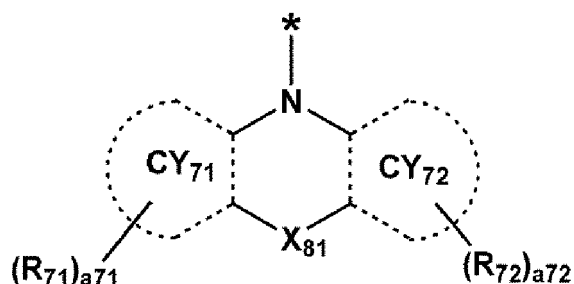
[0056] The organometallic compound is a six-coordinate complex so that the exciplex formation with an organic compound may be suppressed or reduced, thereby improving color purity and luminescence efficiency of the organometallic compound.

[0057] In one embodiment, the second compound may be represented by Formula 2 below, and the third compound may include a group represented by Formula 3 below:

Formula 2



Formula 3



[0058] In Formulae 2 and 3, ring CY₅₁ to ring CY₅₃, ring CY₇₁, and ring CY₇₂ are each independently selected from a C₅-C₃₀ carbocyclic group and a C₁-C₃₀ heterocyclic group. For example, ring CY₅₁ to ring CY₅₃, ring CY₇₁, and ring CY₇₂ may each independently be selected from a C₅-C₂₀ carbocyclic group and a C₁-C₂₀ heterocyclic group.

[0059] In one embodiment, ring CY₅₁ to ring CY₅₃, ring CY₇₁, and CY₇₂ in Formulae 2 and 3 may each independently be i) a first ring, ii) a second ring, iii) a condensed ring in which two or more first rings are condensed with each other (e.g., combined together), iv) a condensed ring in which two or more second rings are condensed with each other (e.g., combined together), or v) a condensed ring in which one or more first rings and one or more second rings are condensed with each other (e.g., combined together),

the first ring may be selected from a cyclopentane group, a cyclopentadiene group, a furan group, a thiophene group, a pyrrole group, a silole group, an oxazole group, an isoxazole group, an oxadiazole group, an isoxadiazole group, an oxatriazole group, an isoxatriazole group, a thiazole group, an isothiazole group, a thiadiazole group, an isothiadiazole group, a thiatriazole group, an isothiatriazole group, a pyrazole group, an imidazole group, a triazole group, a tetrazole group, an azasilole group, a diazasilole group, and a triazasilole group, and

the second ring is selected from an adamantane group, a norbornane group, a norbornene group, a cyclohexane group, a cyclohexene group, a benzene group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a triazine group, an oxasilole group, a thiasilole group, a dihydroazasilole group, a dihydrodisilole group, a dihydrosilole

group, a dioxine group, an oxathiine group, an oxazine group, a pyran group, a dithiine group, a thiazine group, a thiopyran group, a cyclohexadiene group, a dihydropyridine group, and a dihydropyrazine group.

[0060] For example, in Formulae 2 and 3, ring CY₅₁ to ring CY₅₃, ring CY₇₁, and ring CY₇₂ may each independently be selected from a benzene group, a naphthalene group, an anthracene group, a phenanthrene group, a triphenylene group, a pyrene group, a chrysene group, a cyclopentadiene group, a 1,2,3,4-tetrahydronaphthalene group, a thiophene group, a furan group, an indole group, a benzoborole group, a benzophosphole group, an indene group, a benzosilole group, a benzogermole group, a benzothiophene group, a benzoselenophene group, a benzofuran group, a carbazole group, a dibenzoborole group, a dibenzophosphole group, a fluorene group, a dibenzosilole group, a dibenzogermole group, a dibenzothiophene group, a dibenzoselenophene group, a dibenzofuran group, a dibenzothiophene 5-oxide group, a 9H-fluorene-9-one group, a dibenzothiophene 5,5-dioxide group, an azaindole group, an azabenzoborole group, an azabenzophosphole group, an azaindene group, an azabenzosilole group, an azabenzogermole group, an azabenzothiophene group, an azabenzoselenophene group, an azabenzofuran group, an azacarbazole group, an azadibenzoborole group, an azadibenzophosphole group, an azafluorene group, an azadibenzosilole group, an azadibenzogermole group, an azadibenzothiophene group, an azadibenzoselenophene group, an azadibenzofuran group, an azadibenzothiophene 5-oxide group, an aza-9H-fluorene-9-one group, an azadibenzothiophene 5,5-dioxide group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a triazine group, a quinoline group, an isoquinoline group, a quinoxaline group, a quinazoline group, a phenanthroline group, a pyrrole group, a pyrazole group, an imidazole group, a triazole group, an oxazole group, an isoxazole group, a thiazole group, an isothiazole group, an oxadiazole group, a thiadiazole group, a benzopyrazole group, a benzimidazole group, a benzoxazole group, a benzothiazole group, a benzoxadiazole group, a benzothiadiazole group, a 5,6,7,8-tetrahydroisoquinoline group, and a 5,6,7,8-tetrahydroquinoline group, but embodiments of the present disclosure are not limited thereto.

[0061] In Formula 2, L₅₁ to L₅₃ are each independently selected from a substituted or unsubstituted C₅-C₃₀ carbocyclic group and a substituted or unsubstituted C₁-C₃₀ heterocyclic group. For example, in Formulae 2-1 and 2-2, L₅₁ to L₅₃ may each independently be selected from a substituted or unsubstituted C₅-C₂₀ carbocyclic group and a substituted or unsubstituted C₁-C₂₀ heterocyclic group.

[0062] In one embodiment, L₅₁ to L₅₃ in Formula 2 may each independently be selected from: a benzene group, a naphthalene group, an anthracene group, a phenanthrene group, a triphenylene group, a pyrene group, a chrysene group, a cyclopentadiene group, a furan group, a thiophene group, a silole group, an indene group, a fluorene group, an indole group, a carbazole group, a benzofuran group, a dibenzofuran group, a benzothiophene group, a dibenzothiophene group, a benzosilole group, a dibenzosilole group, an azafluorene group, an azacarbazole group, an azadibenzofuran group, an azadibenzothiophene group, an azadibenzosilole group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a triazine group, a quinoline group, an isoquinoline group, a quinoxaline group, a quinazoline group, a phenanthroline group, a pyrrole group, a pyrazole group, an imidazole group, a triazole group, an oxazole group, an isooxazole group, a thiazole group, an isothiazole group, an oxadiazole group, a thiadiazole group, a benzopyrazole group, a benzimidazole group, a benzoxazole group, a benzothiazole group, a benzoxadiazole group, and a benzothiadiazole group;

a benzene group, a naphthalene group, an anthracene group, a phenanthrene group, a triphenylene group, a pyrene group, a chrysene group, a cyclopentadiene group, a furan group, a thiophene group, a silole group, an indene group, a fluorene group, an indole group, a carbazole group, a benzofuran group, a dibenzofuran group, a benzothiophene group, a dibenzothiophene group, a benzosilole group, a dibenzosilole group, an azafluorene group, an azacarbazole group, an azadibenzofuran group, an azadibenzothiophene group, an azadibenzosilole group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a triazine group, a quinoline group, an isoquinoline group, a quinoxaline group, a quinazoline group, a phenanthroline group, a pyrrole group, a pyrazole group, an imidazole group, a triazole group, an oxazole group, an isooxazole group, a thiazole group, an isothiazole group, an oxadiazole group, a thiadiazole group, a benzopyrazole group, a benzimidazole group, a benzoxazole group, a benzothiazole group, a benzoxadiazole group, and a benzothiadiazole 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 (e.g. C₁-C₁₈) alkyl group, a C₁-C₂₀ (e.g. C₁-C₁₈) alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a fluorenyl group, a dimethylfluorenyl group, a diphenylfluorenyl group, a carbazolyl group, a phenylcarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a dimethyldibenzosilolyl group, a diphenyldibenzosilolyl group, -Si(Q₃₁)(Q₃₂)(Q₃₃), -N(Q₃₁)(Q₃₂), -B(Q₃₁)(Q₃₂), -C(=O)(Q₃₁), -S(=O)₂(Q₃₁), and -P(=O)(Q₃₁)(Q₃₂); and

-C(Q₃₁)(Q₃₂)-, *-Si(Q₃₁)(Q₃₂)-*, *-N(Q₃₁)-*, *-B(Q₃₁)-*, *-C(=O)-*, *-S(=O)₂-*, and *-P(=O)(Q₃₁)-*,

Q₃₁ to Q₃₃ may each independently be selected from hydrogen, deuterium, a C₁-C₂₀ (e.g. C₁-C₁₈) alkyl group, a C₁-C₂₀ (e.g. C₁-C₁₈) alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a pyridinyl group, a pyrimidinyl group, a pyridazinyl group, a pyrazinyl group, and a triazinyl group, but embodiments of the present disclosure are not limited thereto, and

* and *' each indicate a binding site to an adjacent atom.

[0063] In Formulae 2 and 3, a bond between L_{51} and ring CY_{51} , a bond between L_{52} and ring CY_{52} , a bond between L_{53} and ring CY_{53} , a bond between two or more $L_{51}(s)$, a bond between two or more $L_{52}(s)$, a bond between two or more $L_{53}(s)$, a bond between L_{51} and carbon between X_{54} and X_{55} in Formula 2, a bond between L_{52} and carbon between X_{54} and X_{56} in Formula 2, and a bond between L_{53} and carbon between X_{55} and X_{56} in Formula 2 may each be a carbon-carbon single bond.

[0064] In Formula 2, b_{51} to b_{53} are each independently an integer from 0 to 5, wherein, when b_{51} is 0, $^{*-(L_{51})_{b_{51}}-^{*}}$ is a single bond, when b_{52} is 0, $^{*-(L_{52})_{b_{52}}-^{*}}$ is a single bond, and when b_{53} is 0, $^{*-(L_{53})_{b_{53}}-^{*}}$ is a single bond,

[0065] For example, b_{51} to b_{53} may each independently be 0, 1, or 2.

[0066] In Formula 2, X_{54} is N or $C(R_{54})$, X_{55} is N or $C(R_{55})$, X_{56} is N or $C(R_{56})$, and at least one selected from X_{54} to X_{56} is N, and R_{54} to R_{56} are each independently the same as described in the detailed description.

[0067] In Formula 3, X_{81} is a single bond, O, S, $N(R_{81})$, $B(R_{81})$, $C(R_{81a})(R_{81b})$, or $Si(R_{81a})(R_{81b})$. R_{81} , R_{81a} , and R_{81b} are each independently the same as described in the detailed description.

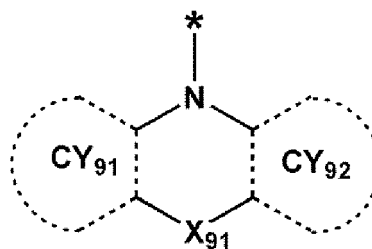
[0068] In Formulae 2 and 3, R_{51} to R_{56} , R_{71} , R_{72} , R_{81} , R_{81a} , and R_{81b} are each independently selected from hydrogen, deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1-C_{60} (e.g. C_1-C_{20}) alkyl group, a substituted or unsubstituted C_2-C_{60} (e.g. C_2-C_{20}) alkenyl group, a substituted or unsubstituted C_2-C_{60} (e.g. C_2-C_{20}) alkynyl group, a substituted or unsubstituted C_1-C_{60} (e.g. C_1-C_{20}) alkoxy group, a substituted or unsubstituted C_3-C_{18} cycloalkyl group, a substituted or unsubstituted C_1-C_{18} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{18} cycloalkenyl group, a substituted or unsubstituted C_1-C_{18} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} (e.g. C_6-C_{30}) aryl group, a substituted or unsubstituted C_7-C_{60} (e.g. C_7-C_{30}) alkylaryl group, a substituted or unsubstituted C_6-C_{60} (e.g. C_6-C_{30}) aryloxy group, a substituted or unsubstituted C_6-C_{60} (e.g. C_6-C_{30}) arylthio group, a substituted or unsubstituted C_1-C_{60} (e.g. C_1-C_{20}) heteroaryl group, a substituted or unsubstituted C_2-C_{60} (e.g. C_2-C_{20}) alkylheteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, - $Si(Q_1)(Q_2)(Q_3)$, - $N(Q_1)(Q_2)$, - $B(Q_1)(Q_2)$, - $C(=O)(Q_1)$, - $S(=O)_2(Q_1)$, and - $P(=O)(Q_1)(Q_2)$, and Q_1 to Q_3 may each be the same as described elsewhere in the present specification.

[0069] In one embodiment, R_{51} to R_{56} , R_{71} , R_{72} , R_{81} , R_{81a} , and R_{81b} in Formulae 2 and 3 may each independently be selected from:

hydrogen, deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{60} (e.g. C_1-C_{20}) alkyl group, and a C_1-C_{60} (e.g. C_1-C_{20}) alkoxy group; a C_1-C_{60} (e.g. C_1-C_{20}) alkyl group and a C_1-C_{60} (e.g. C_1-C_{20}) alkoxy group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, - CD_3 , - CD_2H , - CDH_2 , - CF_3 , - CF_2H , - CFH_2 , a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a biphenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group; a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl 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 perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl 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 benzoquinolinyl group, a benzoisoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, a benzoisothiazolyl group, a benzoxazolyl group, a benzoisoxazolyl group, a triazolyl group, a tetrazolyl group, a thiadiazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphthosilolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafluorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indeno carbazolyl group, and an indolocarbazolyl group; a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a nor-

bornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl 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 perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl 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 benzoquinolinyl group, a benzoisoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, a benzoisothiazolyl group, a benzoxazolyl group, a benzoisoxazolyl group, a triazolyl group, a tetrazolyl group, a thiadiazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphtho silolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafuorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indeno carbazolyl group, an indolocarbazolyl group, and a group represented by Formula 91, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, -CD₃, -CD₂H, -CDH₂, -CF₃, -CF₂H, -CFH₂, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ (e.g. C₁-C₂₀) alkyl group, a C₁-C₆₀ (e.g. C₁-C₂₀) alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl 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 perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl 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 benzoquinolinyl group, a benzoisoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, a benzoisothiazolyl group, a benzoxazolyl group, a benzoisoxazolyl group, a triazolyl group, a tetrazolyl group, a thiadiazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphtho silolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafuorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indeno carbazolyl group, an indolocarbazolyl group, -Si(Q₃₁)(Q₃₂)(Q₃₃), -N(Q₃₁)(Q₃₂), -B(Q₃₁)(Q₃₂), -C(=O)(Q₃₁), -S(=O)₂(Q₃₁), and -P(=O)(Q₃₁)(Q₃₂); and -Si(Q₁)(Q₂)(Q₃), -N(Q₁)(Q₂), -B(Q₁)(Q₂), -C(=O)(Q₁), -S(=O)₂(Q₁), and -P(=O)(Q₁)(Q₂), and Q₁ to Q₃ 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 (e.g. C₁-C₂₀) alkyl group, a C₂-C₆₀ (e.g. C₂-C₂₀) alkenyl group, a C₂-C₆₀ (e.g. C₂-C₂₀) alkynyl group, a C₁-C₆₀ (e.g. C₁-C₂₀) alkoxy group, a C₃-C₁₈ cycloalkyl group, a C₁-C₁₈ heterocycloalkyl group, a C₃-C₁₈ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ (e.g. C₆-C₃₀) aryl group, a C₆-C₆₀ (e.g. C₆-C₃₀) aryloxy group, a C₆-C₆₀ (e.g. C₆-C₃₀) arylthio group, a C₁-C₆₀ (e.g. C₁-C₂₀) heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a C₁-C₆₀ (e.g. C₁-C₂₀) alkyl group that is substituted with at least one selected from deuterium, -F, a cyano group, a C₁-C₆₀ (e.g. C₁-C₂₀) alkyl group, a phenyl group, and a biphenyl group, a C₆-C₆₀ (e.g. C₆-C₃₀) aryl group that is substituted with at least one selected from deuterium, -F, a cyano group, a C₁-C₁₈ alkyl group, a phenyl group, and a biphenyl group, and a C₁-C₆₀ (e.g. C₁-C₂₀) heteroaryl group that is substituted with at least one selected from deuterium, -F, a cyano group, a C₁-C₁₈ alkyl group, a phenyl group, and a biphenyl group, but embodiments of the present disclosure are not limited thereto:

Formula 91



[0070] In Formula 91,

ring CY₉₁ and ring CY₉₂ are each independently selected from a C₅-C₃₀ (e.g. C₅-C₂₀) carbocyclic group and a C₁-C₃₀ (e.g. C₁-C₂₀) heterocyclic group,

X₉₁ is a single bond, O, S, N(R₉₁), B(R₉₁), C(R_{91a})(R_{91b}), or Si(R_{91a})(R_{91b}),

R₉₁, R_{91a}, and R_{91b} are each independently the same as described in connection with R₈₁, R_{81a}, and R_{81b}, respectively, in the present specification, and

* indicates a binding site to a neighboring atom.

[0071] For example, in Formula 91,

ring CY₉₁ and ring CY₉₂ may each independently be selected from a benzene group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, and a triazine group,

R₉₁, R_{91a}, and R_{91b} may each independently be selected from:

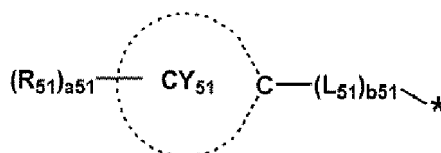
hydrogen and a C₁-C₁₈ alkyl group;

a phenyl group, a biphenyl group, a pyridinyl group, a pyrimidinyl group, a pyridazinyl group, a pyrazinyl group, and a triazinyl group; and

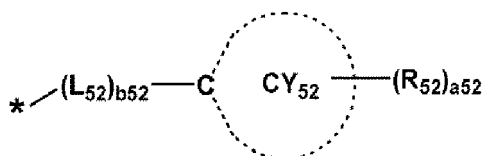
a phenyl group, a pyridinyl group, a pyrimidinyl group, a pyridazinyl group, a pyrazinyl group, and a triazinyl group, each substituted with at least one selected from deuterium, a C₁-C₁₈ alkyl group, a phenyl group, a biphenyl group, a pyridinyl group, a pyrimidinyl group, a pyridazinyl group, a pyrazinyl group, and a triazinyl group, but embodiments of the present disclosure are not limited thereto.

[0072] In Formulae 2 and 3, a₅₁ to a₅₃, a₇₁, and a₇₂ indicate the number of R₅₁ to R₅₃, the number of R₇₁, the number of R₇₂, respectively, and are each independently an integer from 0 to 10. When a₅₁ is 2 or more, two or more R₅₁(s) may be identical to each other or different from each other, and a₅₂, a₅₃, a₇₁, and a₇₂ may each be understood in this manner.

[0073] In one embodiment, in Formula 2, a group represented by

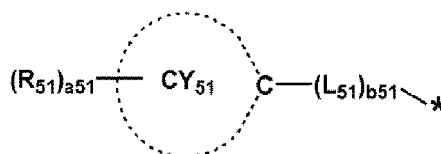


and a group represented by

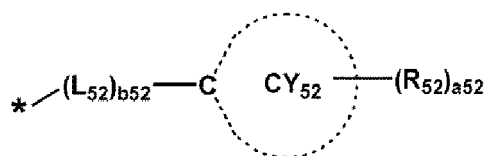


may not each be a phenyl group (or may not both be a phenyl group).

[0074] In one or more embodiments, in Formula 2, a group represented by



and a group represented by



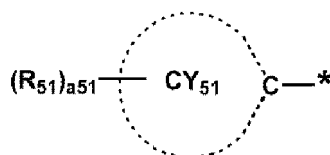
may be identical to each other (e.g., may both be the same as each other).

10 **[0075]** In one or more embodiments, in Formula 2, ring CY_{51} and ring CY_{52} may each independently be selected from a benzene group, a pyridine group, a pyrimidine group, a pyridazine group, a pyrazine group, and a triazine group, R_{51} and R_{52} may each independently be selected from a substituted or unsubstituted C_3 - C_{18} cycloalkyl group, a substituted or unsubstituted C_1 - C_{18} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{18} cycloalkenyl group, a substituted or unsubstituted C_1 - C_{18} heterocycloalkenyl group, a substituted or unsubstituted C_6 - C_{60} (e.g. C_6 - C_{30}) aryl group, a substituted or unsubstituted C_7 - C_{60} (e.g. C_7 - C_{30}) alkylaryl group, a substituted or unsubstituted C_6 - C_{60} (e.g. C_6 - C_{30}) aryloxy group, a substituted or unsubstituted C_6 - C_{60} (e.g. C_6 - C_{30}) arylthio group, a substituted or unsubstituted C_1 - C_{60} (e.g. C_1 - C_{20}) heteroaryl group, a substituted or unsubstituted C_2 - C_{60} (e.g. C_2 - C_{20}) alkylheteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, and $-Si(Q_1)(Q_2)(Q_3)$,

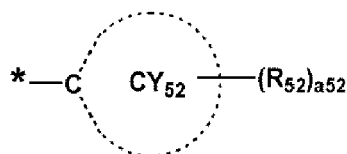
20 Q_1 to Q_3 may each independently be selected from a C_3 - C_{10} cycloalkyl group, a C_1 - C_{18} heterocycloalkyl group, a C_3 - C_{18} cycloalkenyl group, a C_1 - C_{18} heterocycloalkenyl group, a C_6 - C_{60} (e.g. C_6 - C_{30}) aryl group, a C_6 - C_{60} (e.g. C_6 - C_{30}) aryloxy group, a C_6 - C_{60} (e.g. C_6 - C_{30}) arylthio group, a C_1 - C_{60} (e.g. C_1 - C_{20}) heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, and a C_6 - C_{60} (e.g. C_6 - C_{30}) aryl group that is substituted with at least one selected from deuterium, -F, a cyano group, a C_1 - C_{18} alkyl group, a phenyl group, and a biphenyl group, and

25 a_{51} and a_{52} may each independently be 1, 2, or 3.

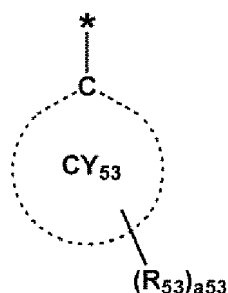
[0076] In one or more embodiments, in Formula 2, a moiety represented by



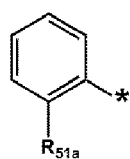
35 may be selected from groups represented by Formulae CY_{51} - 1 to CY_{51} -18 below (and/or), a moiety represented by



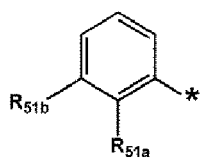
45 may be selected from groups represented by Formulae CY_{52} -1 to CY_{52} -18 below (and/or), a moiety represented by



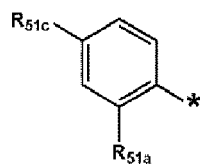
may be selected from groups represented by Formulae CY_{53} -1 to CY_{53} -19 below:



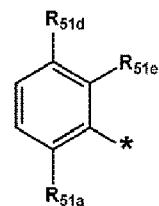
CY51-1



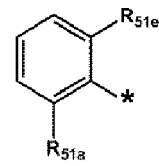
CY51-2



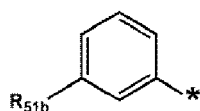
CY51-3



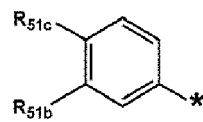
CY51-4



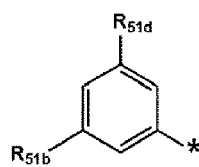
CY51-5



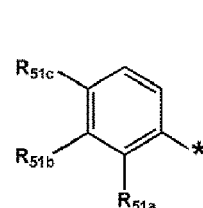
CY51-6



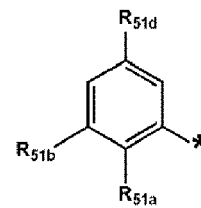
CY51-7



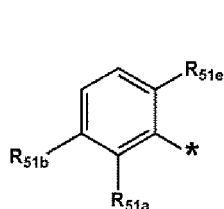
CY51-8



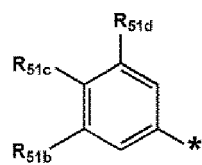
CY51-9



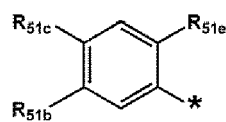
CY51-10



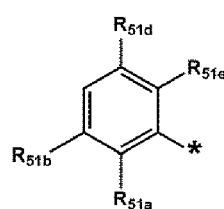
CY51-11



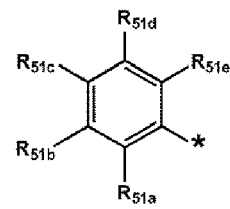
CY51-12



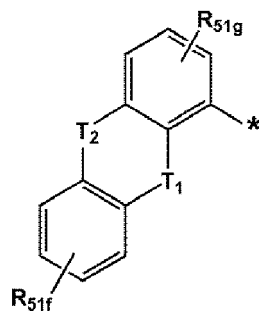
CY51-13



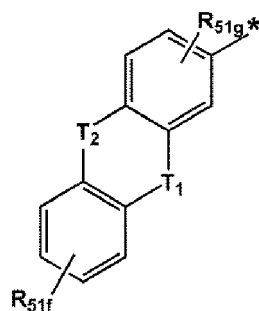
CY51-14



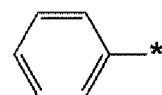
CY51-15



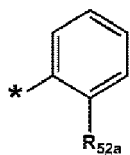
CY51-16



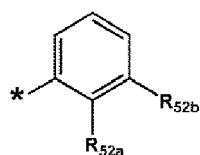
CY51-17



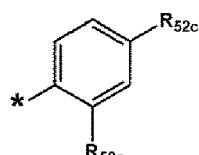
CY51-18



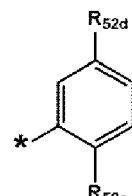
CY52-1



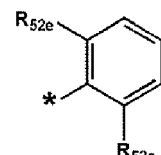
CY52-2



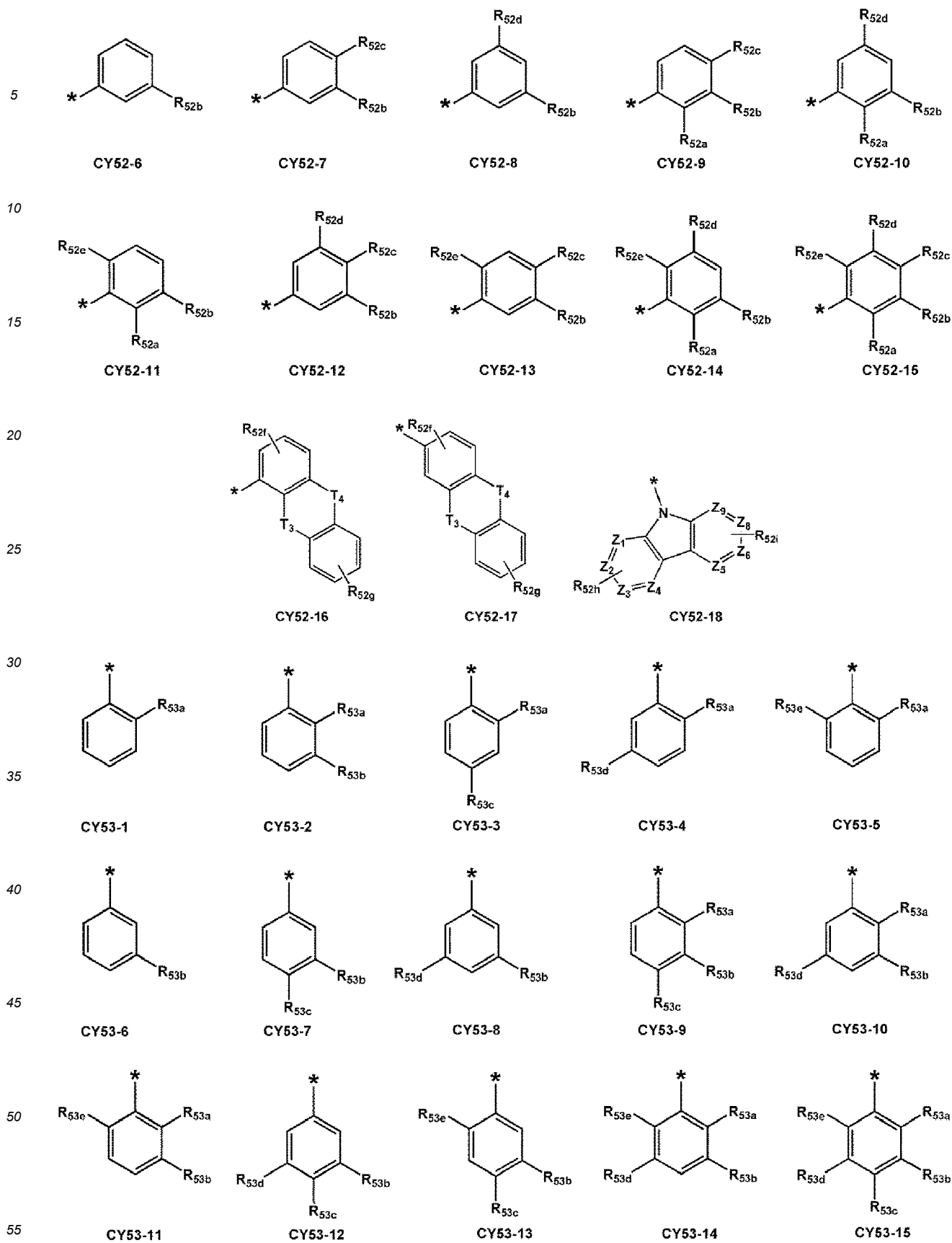
CY52-3

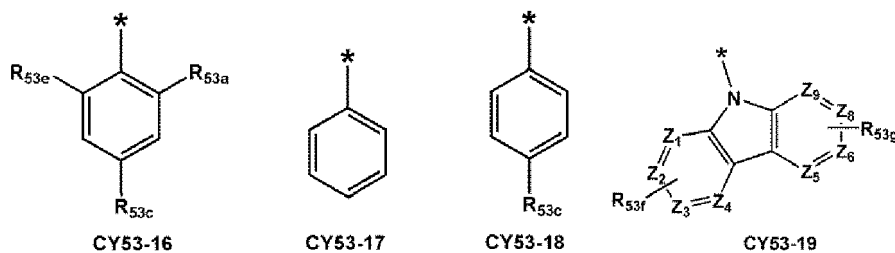


CY52-4



CY52-5





[0077] In Formulae CY51-1 to CY51-18, CY52-1 to CY52-18, and CY53-1 to CY53-19,

T_1 is a single bond, O, S, N(T_{11}), B(T_{11}), C(T_{11})(T_{12}), or Si(T_{11})(T_{12}),

T_2 is a single bond, O, S, N(T_{21}), B(T_{21}), C(T_{21})(T_{22}), or Si(T_{21})(T_{22}),

T_3 is a single bond, O, S, N(T_{31}), B(T_{31}), C(T_{31})(T_{32}), or Si(T_{31})(T_{32}),

T_4 is a single bond, O, S, N(T_{41}), B(T_{41}), C(T_{41})(T_{42}), or Si(T_{41})(T_{42}),

T_1 and T_2 in Formulae CY51-16 and CY51-17 are not each a single bond at the same time,

T_3 and T_4 in Formulae CY51-16 and CY51-17 are not each a single bond at the same time,

R_{51a} to R_{51g} , T_{11} , T_{12} , T_{21} , and T_{22} are each the same as described in connection with R_{51} in the present specification, wherein R_{51a} to R_{51e} are not each hydrogen,

R_{52a} to R_{52i} , T_{31} , T_{32} , T_{41} , and T_{42} are each the same as described in connection with R_{52} in the present specification, wherein R_{52a} to R_{52e} are not each hydrogen,

R_{53a} to R_{53g} are each independently the same as described in connection with R_{53} in the present disclosure, wherein R_{53a} to R_{53e} are not each hydrogen,

Z_1 to Z_9 in Formulae CY52-18 and CY53-19 are each independently C or N, and

* indicates a binding site to a neighboring atom.

[0078] For example, in Formulae CY51-1 to CY51-15 and CY52-1 to 52-15, R_{51a} to R_{51e} and R_{52a} to R_{52e} may each independently be selected from:

a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a biphenyl group, a C_1 - C_{18} alkylphenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinoliny group, an isoquinoliny group, a benzoquinoliny group, a quinoxaliny group, a quinazoliny group, a cinnoliny group, a carbazolyl group, a phenanthroliny group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azafluorenyl group, an azadibenzosilolyl group, and a group represented by Formula 91;

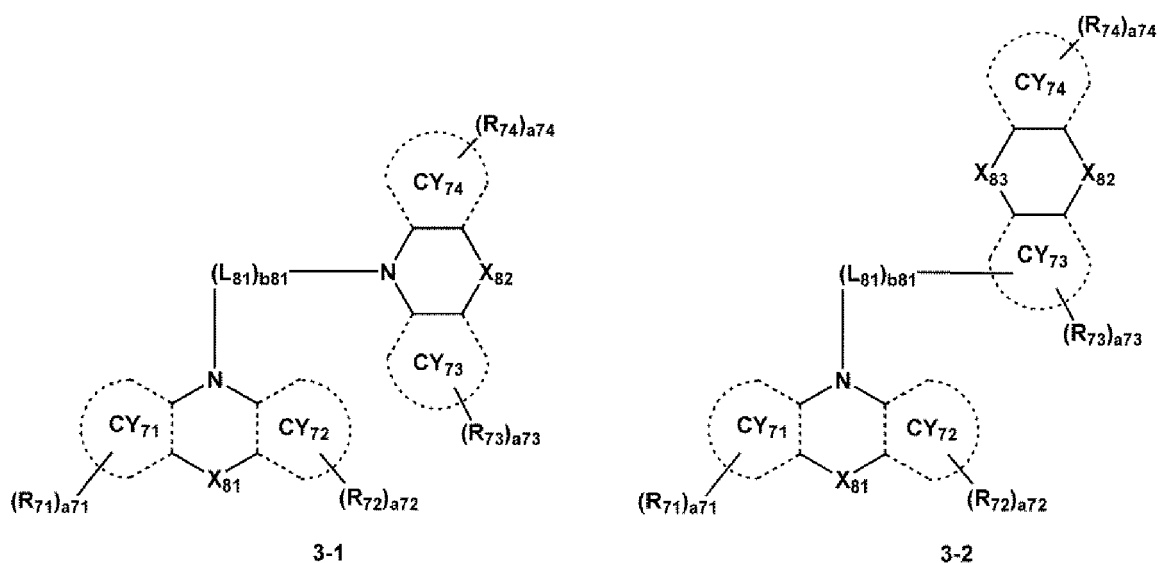
a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a biphenyl group, a C_1 - C_{18} alkylphenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinoliny group, an isoquinoliny group, a benzoquinoliny group, a quinoxaliny group, a quinazoliny group, a cinnoliny group, a carbazolyl group, a phenanthroliny group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azafluorenyl group, an azadibenzosilolyl group, and a group represented by Formula 91, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, -CD₃, -CD₂H, -CDH₂, -CF₃, -CF₂H, -CFH₂, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} (e.g. C_1 - C_{10}) alkyl group, a C_1 - C_{20} (e.g. C_1 - C_{18}) alkoxy group, a cyclopentyl group, a cyclohexyl

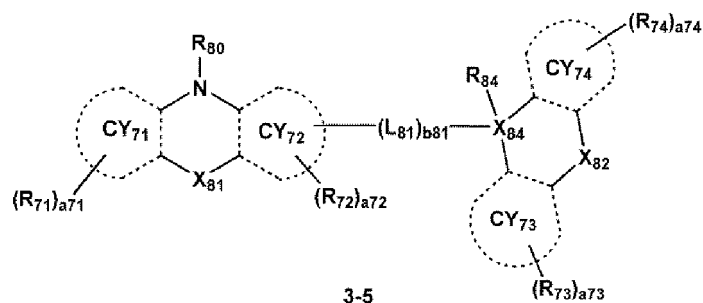
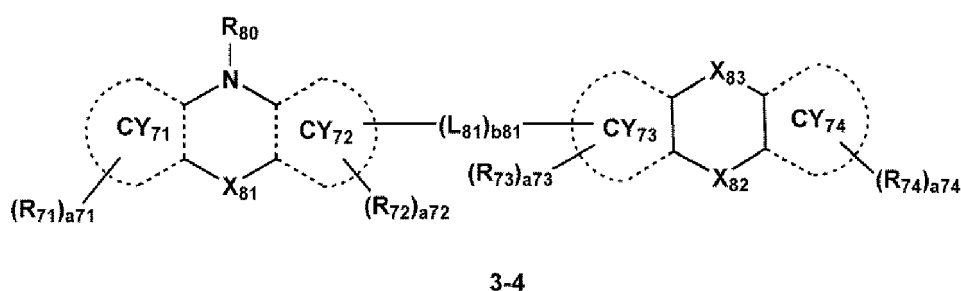
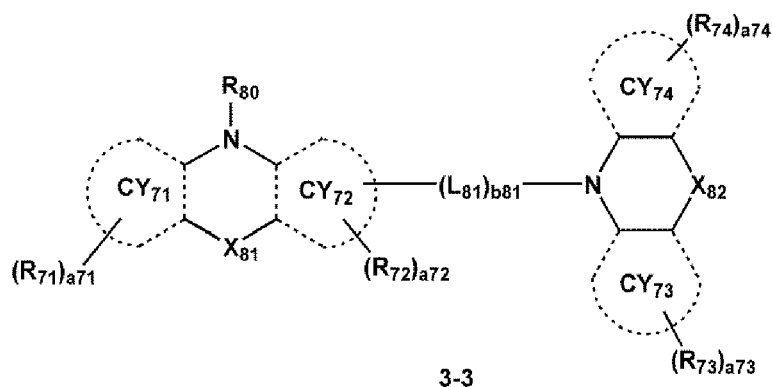
group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a biphenyl group, a C₁-C₁₈ alkylphenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazoyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group; and
 -C(Q₁)(Q₂)(Q₃) and -Si(Q₁)(Q₂)(Q₃),
 Q₁ to Q₃ may each independently be selected from:

a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a pyridazinyl group, a pyrazinyl group, and a triazinyl group; and
 a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a pyridazinyl group, a pyrazinyl group, and a triazinyl group, each substituted with at least one selected from deuterium, a C₁-C₁₈ alkyl group, a phenyl group, a biphenyl group, a pyridinyl group, a pyrimidinyl group, a pyridazinyl group, a pyrazinyl group, and a triazinyl group, and

in Formulae CY51-16 and CY51-17, i) T₁ may be O or S, and T₂ may be Si(T₂₁)(T₂₂), or ii) T₁ may be Si(T₁₁)(T₁₂), and T₂ may be O or S, and
 in Formulae CY52-16 and CY52-17, i) T₃ may be O or S, and T₄ may be Si(T₄₁)(T₄₂), or ii) T₃ may be Si(T₃₁)(T₃₂), and T₄ may be O or S, but embodiments of the present disclosure are not limited thereto.

[0079] In one or more embodiments, the third compound may be represented by one of Formulae 3-1 to 3-5 below:





[0080] In Formulae 3-1 to 3-5,

ring CY₇₁, ring CY₇₂, X₈₁, R₇₁, R₇₂, a₇₁, and a₇₂ are each independently the same as described elsewhere in the present specification,

ring CY₇₃, ring CY₇₄, R₇₃, R₇₄, a₇₃, and a₇₄ are each independently the same as described in connection with ring CY₇₁, ring CY₇₂, R₇₁, R₇₂, a₇₁, and a₇₂, respectively, in the present specification,

L₈₁ is selected from *-C(Q₄)(Q₅)-*, *-Si(Q₄)(Q₅)-*, a substituted or unsubstituted C₅-C₃₀ (e.g. C₅-C₂₀) carbocyclic group, and a substituted or unsubstituted C₁-C₃₀ (e.g. C₁-C₂₀) heterocyclic group, wherein Q₄ and Q₅ are each independently the same as described in connection with Q₁ in the present specification,

b₈₁ is an integer from 0 to 5, wherein, when b₈₁ is 0, *-(L₈₁)_{b81}-* is a single bond, and when b₈₁ is 2 or more, two or more L₈₁(s) may be identical to or different from each other,

X₈₂ is a single bond, O, S, N(R₈₂), B(R₈₂), C(R_{82a})(R_{82b}), or Si(R_{82a})(R_{82b}),

X₈₃ is a single bond, O, S, N(R₈₃), B(R₈₃), C(R_{83a})(R_{83b}), or Si(R_{83a})(R_{83b}),

in Formulae 3-2 and 3-4, X₈₂ and X₈₃ are not each a single bond at the same time,

X₈₄ is C or Si,

R₈₀, R₈₂, R₈₃, R_{82a}, R_{82b}, R_{83a}, R_{83b}, and R₈₄ are each independently the same as described in connection with R₈₁ in the present specification, and

* and * each indicate a binding site to a neighboring atom.

[0081] For example, L₈₁ may be selected from:

-C(Q₄)(Q₅)- and *-Si(Q₄)(Q₅)-*;

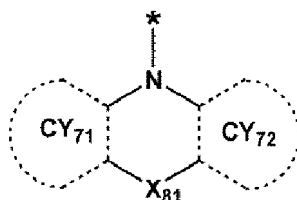
a benzene group, a naphthalene group, an anthracene group, a phenanthrene group, a triphenylene group, a pyrene group, a chrysene group, a cyclopentadiene group, a furan group, a thiophene group, a silole group, an indene

group, a fluorene group, an indole group, a carbazole group, a benzofuran group, a dibenzofuran group, a benzothiophene group, a dibenzothiophene group, a benzosilole group, a dibenzosilole group, an azafluorene group, an azacarbazole group, an azadibenzofuran group, an azadibenzothiophene group, an azadibenzosilole group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a triazine group, a quinoline group, an isoquinoline group, a quinoxaline group, a quinazoline group, a phenanthroline group, a pyrrole group, a pyrazole group, an imidazole group, a triazole group, an oxazole group, an isoxazole group, a thiazole group, an isothiazole group, an oxadiazole group, a thiadiazole group, a benzopyrazole group, a benzimidazole group, a benzoxazole group, a benzothiazole group, a benzooxadiazole group, and a benzothiadiazole group; and

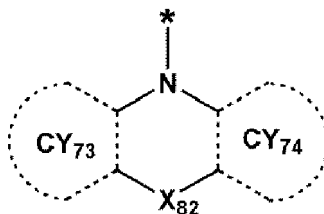
a benzene group, a naphthalene group, an anthracene group, a phenanthrene group, a triphenylene group, a pyrene group, a chrysene group, a cyclopentadiene group, a furan group, a thiophene group, a silole group, an indene group, a fluorene group, an indole group, a carbazole group, a benzofuran group, a dibenzofuran group, a benzothiophene group, a dibenzothiophene group, a benzosilole group, a dibenzosilole group, an azafluorene group, an azacarbazole group, an azadibenzofuran group, an azadibenzothiophene group, an azadibenzosilole group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a triazine group, a quinoline group, an isoquinoline group, a quinoxaline group, a quinazoline group, a phenanthroline group, a pyrrole group, a pyrazole group, an imidazole group, a triazole group, an oxazole group, an isooxazole group, a thiazole group, an isothiazole group, an oxadiazole group, a thiadiazole group, a benzopyrazole group, a benzimidazole group, a benzoxazole group, a benzothiazole group, a benzooxadiazole group, and a benzothiadiazole 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 (e.g. C₁-C₁₈) alkyl group, a C₁-C₂₀ (e.g. C₁-C₁₈) alkoxy group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a fluorenyl group, a dimethylfluorenyl group, a diphenylfluorenyl group, a carbazolyl group, a phenylcarbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a dimethyldibenzosilolyl group, a diphenyldibenzosilolyl group, -O(Q₃₁), -S(Q₃₁), -Si(Q₃₁)(Q₃₂)(Q₃₃), -N(Q₃₁)(Q₃₂), -B(Q₃₁)(Q₃₂), -P(Q₃₁)(Q₃₂), -C(=O)(Q₃₁), -S(=O)₂(Q₃₁), and -P(=O)(O₃₁)(O₃₂), and

Q₄, Q₅, and Q₃₁ to Q₃₃ may each independently be selected from hydrogen, deuterium, a C₁-C₂₀ (e.g. C₁-C₁₈) alkyl group, a C₁-C₂₀ (e.g. C₁-C₁₀) alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a pyridinyl group, a pyrimidinyl group, a pyridazinyl group, a pyrazinyl group, and a triazinyl group, but embodiments of the present disclosure are not limited thereto.

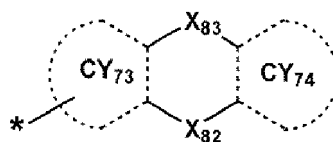
[0082] For example, a moiety represented by



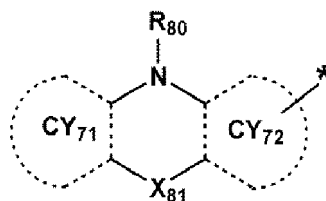
in Formulae 3-1 and 3-2 may be selected from groups represented by Formulae CY71-1(1) to CY71-1 (8) below, a moiety represented by



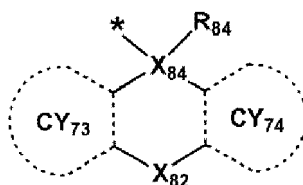
in Formulae 3-1 and 3-3 may be selected from groups represented by Formulae CY71-2(1) to CY71-2(8) below, a moiety represented by



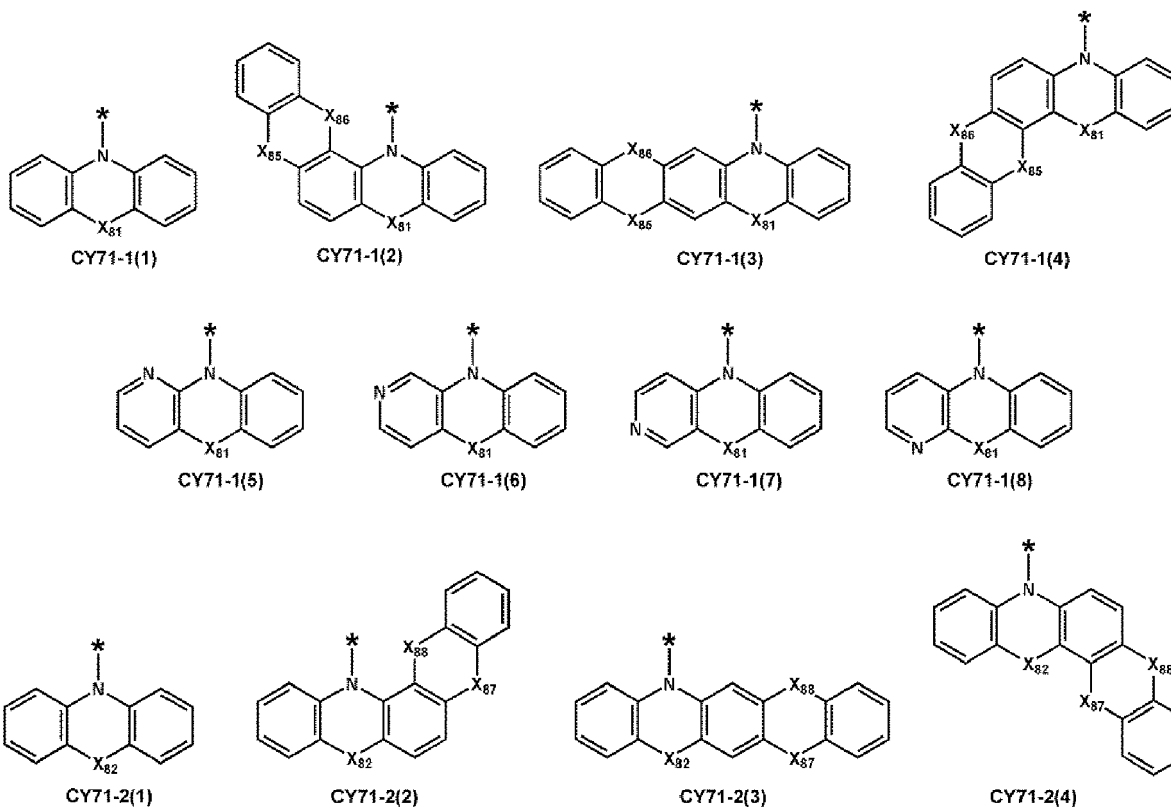
in Formulae 3-2 and 3-4 may be selected from groups represented by Formulae CY71-3(1) to CY71-3(32) below, a moiety represented by

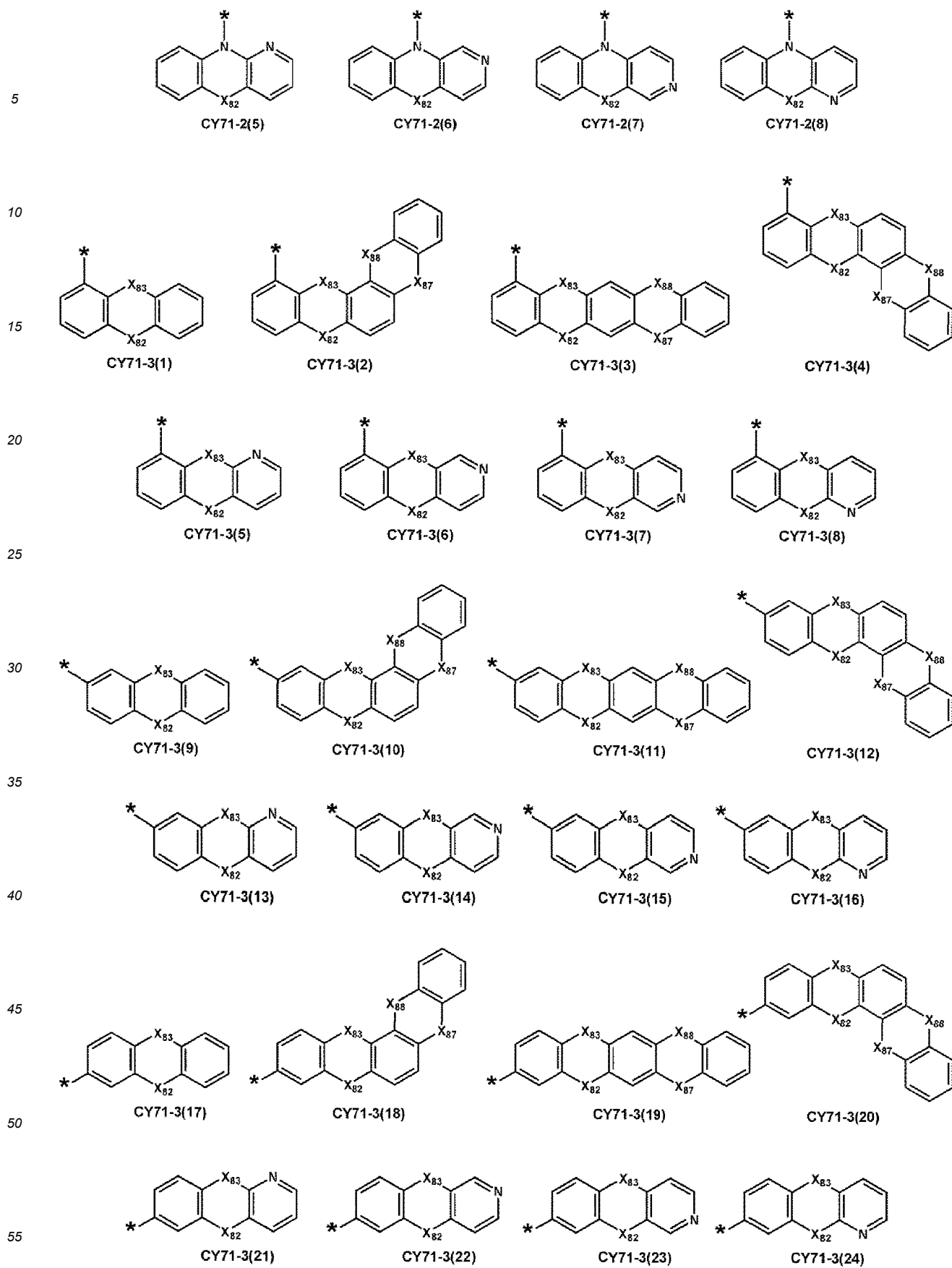


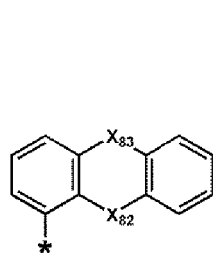
in Formulae 3-3 to 3-5 may be selected from groups represented by Formulae CY71-4(1) to CY71-4(32) below, and a moiety represented by



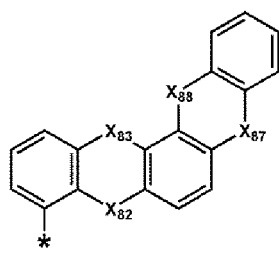
in Formula 3-5 may be selected from groups represented by Formulae CY71-5(1) to CY71-5(8), but embodiments of the present disclosure are not limited thereto:



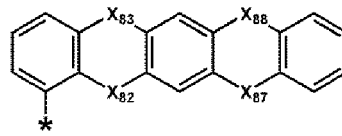




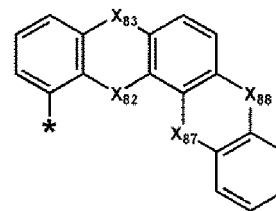
CY71-3(25)



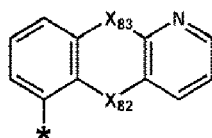
CY71-3(26)



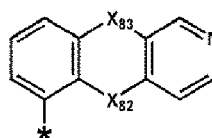
CY71-3(27)



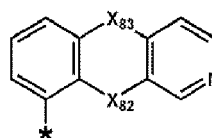
CY71-3(28)



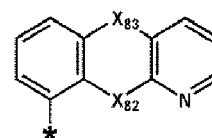
CY71-3(29)



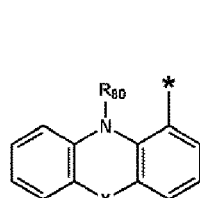
CY71-3(30)



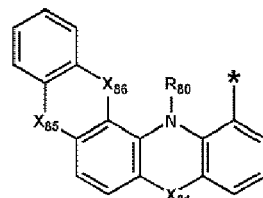
CY71-3(31)



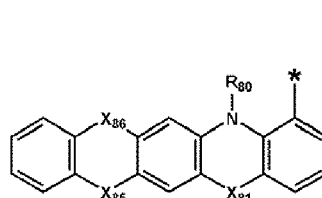
CY71-3(32)



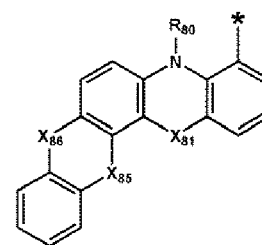
CY71-4(1)



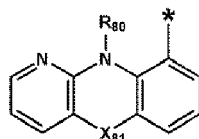
CY71-4(2)



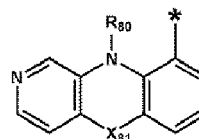
CY71-4(3)



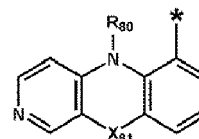
CY71-4(4)



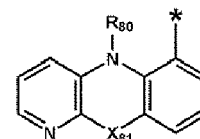
CY71-4(5)



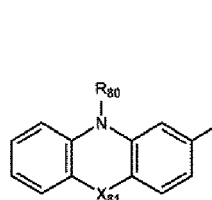
CY71-4(6)



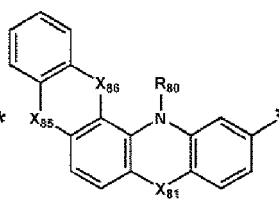
CY71-4(7)



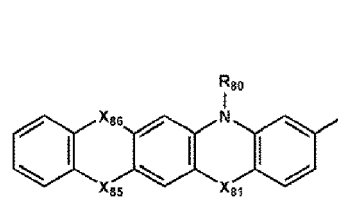
CY71-4(8)



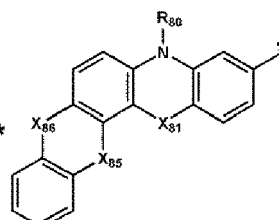
CY71-4(9)



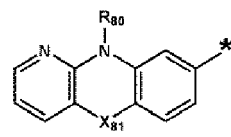
CY71-4(10)



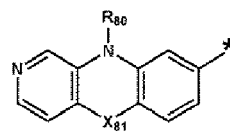
CY71-4(11)



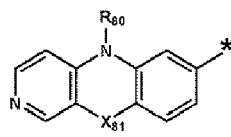
CY71-4(12)



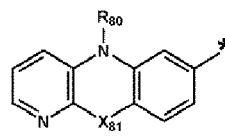
CY71-4(13)



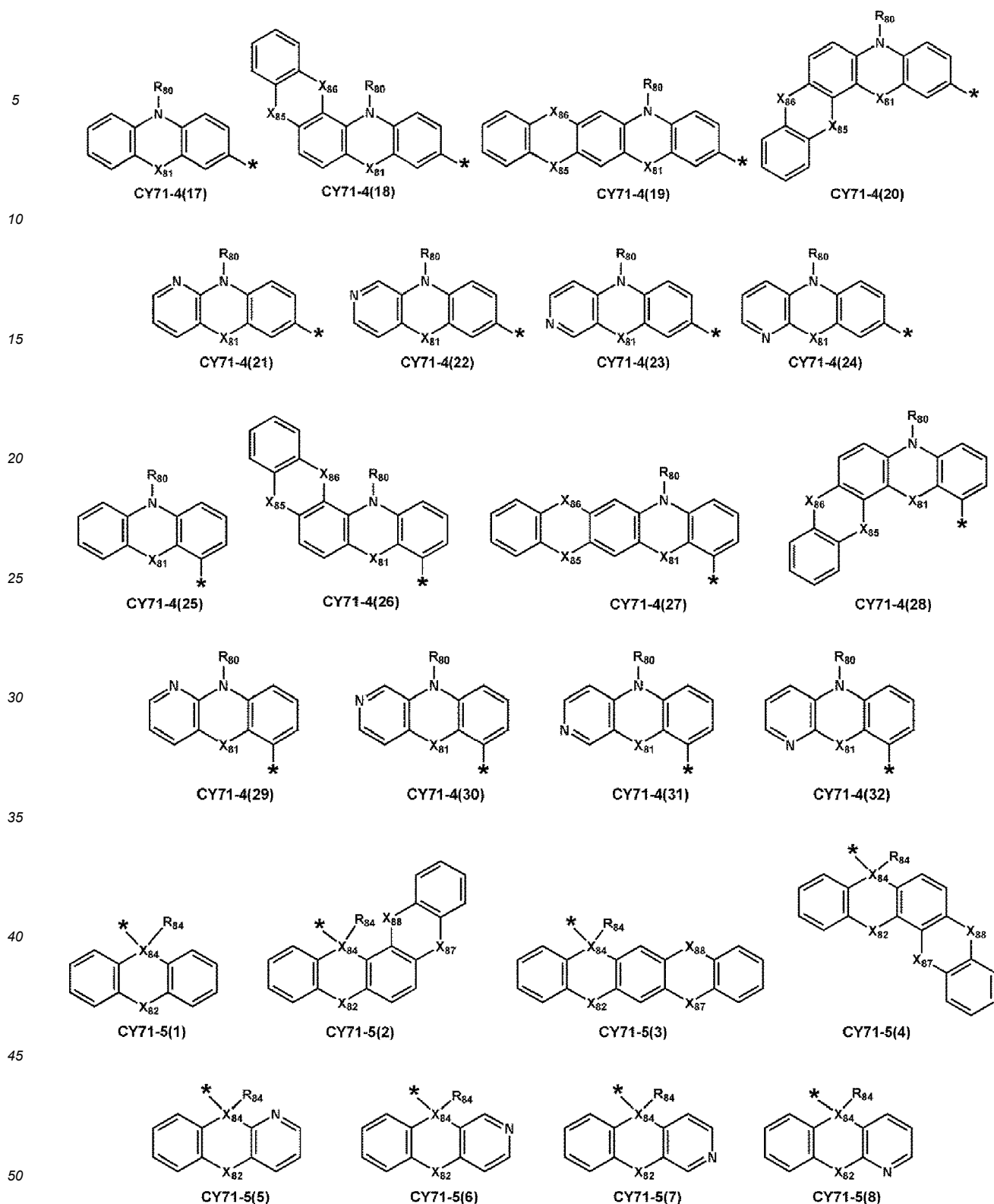
CY71-4(14)



CY71-4(15)



CY71-4(16)



[0083] In Formulae CY71-1(1) to CY71-1(8), CY71-2(1) to CY71-2(8), CY71-3(1) to CY71-3(32), CY71-4(1) to CY71-4(32), and CY71-5(1) to CY71-5(8),

X₈₁ to X₈₄, R₈₀, and R₈₄ are each independently the same as described elsewhere in the present specification,

X₈₅ is a single bond, O, S, N(R₈₅), B(R₈₅), C(R_{85a})(R_{85b}), or Si(R_{85a})(R_{85b}),

X₈₆ is a single bond, O, S, N(R₈₆), B(R₈₆), C(R_{86a})(R_{86b}), or Si(R_{86a})(R_{86b}),

in Formulae CY71-1(1) to CY71-1(8) and CY71-4(1) to CY71-4(32), X₈₅ and X₈₆ are not each a single bond at the same

time,

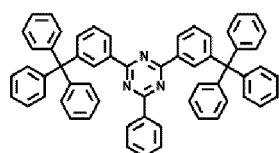
X_{87} is a single bond, O, S, N(R_{87}), B(R_{87}), C(R_{87a})(R_{87b}), or Si(R_{87a})(R_{87b}),

X_{88} is a single bond, O, S, N(R_{88}), B(R_{88}), C(R_{88a})(R_{88b}), or Si(R_{88a})(R_{88b}),

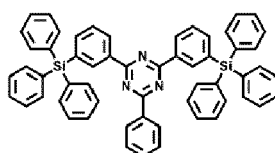
in Formulae CY71-2(1) to CY71-2(8), CY71-3(1) to CY71-3(32), and CY71-5(1) to CY71-5(8), X_{87} and X_{88} are not each a single bond at the same time, and

R_{85} to R_{88} , R_{85a} , R_{85b} , R_{86a} , R_{86b} , R_{87a} , R_{87b} , R_{88a} , and R_{88b} are each independently the same as described in connection with R_{81} in the present specification.

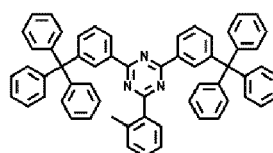
[0084] In one embodiment, the second compound may be selected from Compounds ETH1 to ETH80 below:



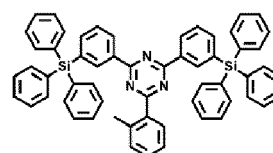
ETH1



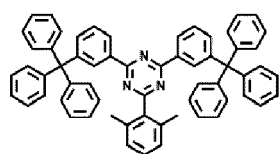
ETH2



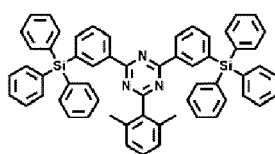
ETH3



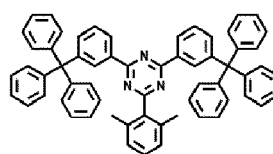
ETH4



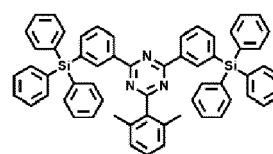
ETH5



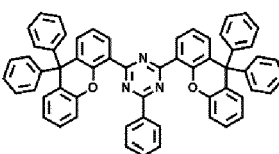
ETH6



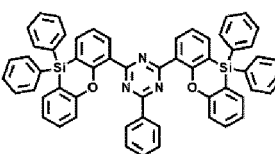
ETH7



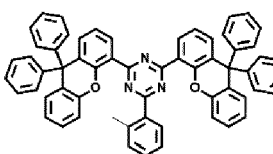
ETH8



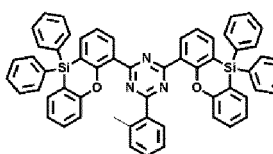
ETH9



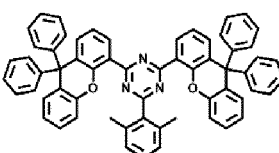
ETH10



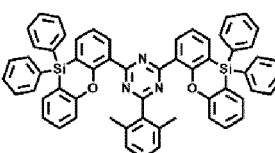
ETH11



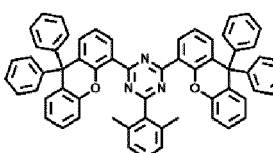
ETH12



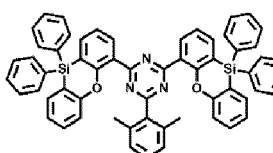
ETH13



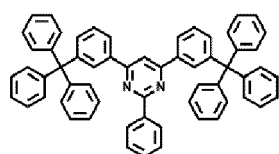
ETH14



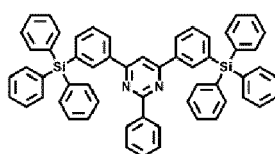
ETH15



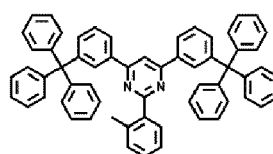
ETH16



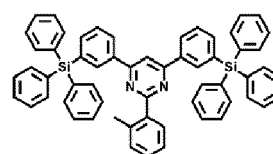
ETH17



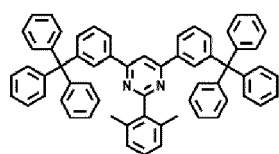
ETH18



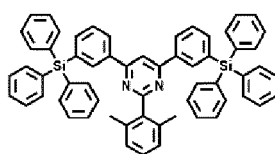
ETH19



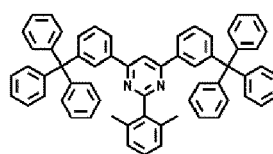
ETH20



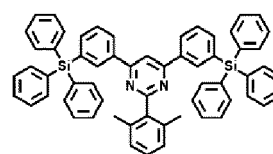
ETH21



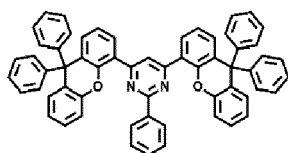
ETH22



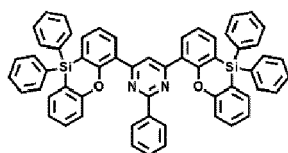
ETH23



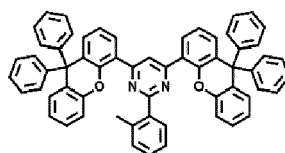
ETH24



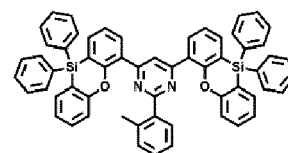
ETH25



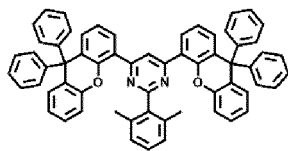
ETH26



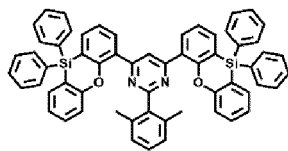
ETH27



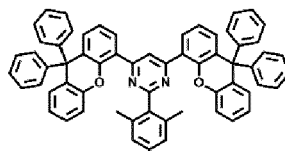
ETH28



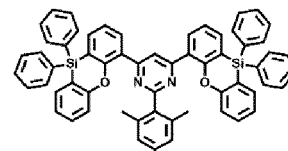
ETH29



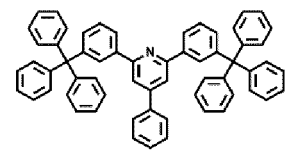
ETH30



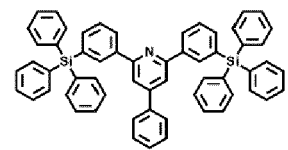
ETH31



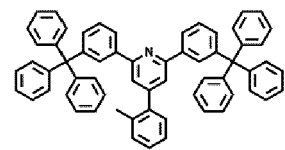
ETH32



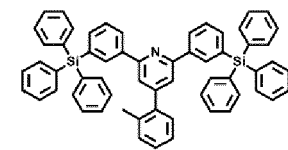
ETH33



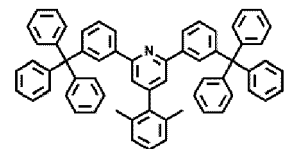
ETH34



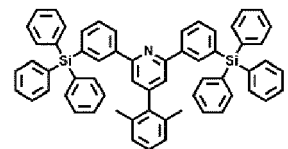
ETH35



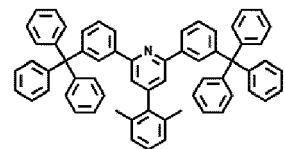
ETH36



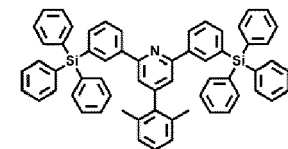
ETH37



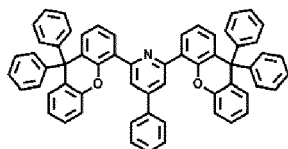
ETH38



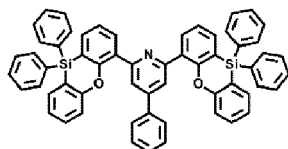
ETH39



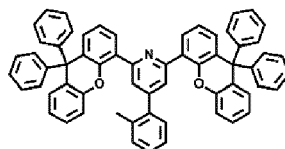
ETH40



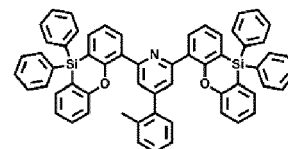
ETH41



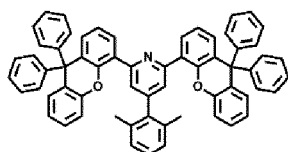
ETH42



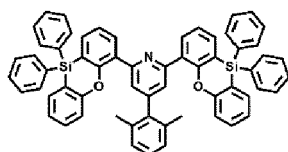
ETH43



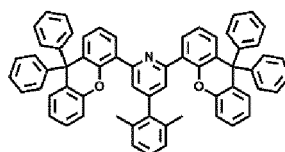
ETH44



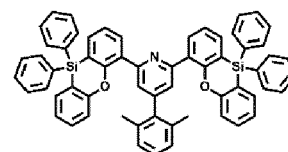
ETH45



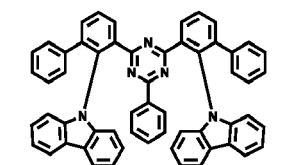
ETH46



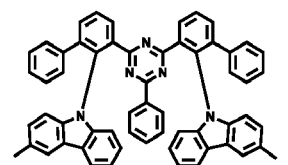
ETH47



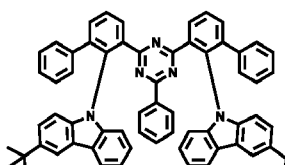
ETH48



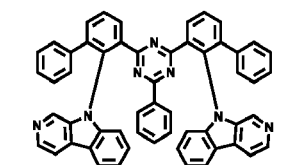
ETH49



ETH50

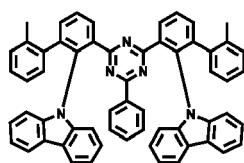


ETH51

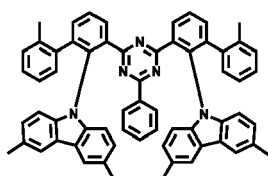


ETH52

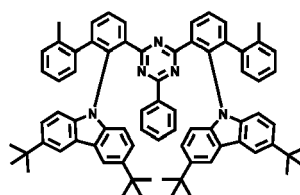
5



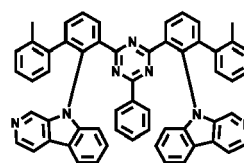
ETH53



ETH54

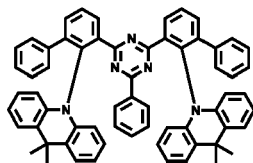


ETH55

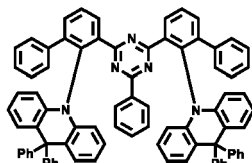


ETH56

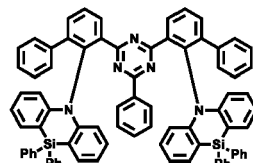
10



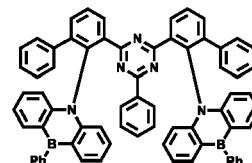
ETH57



ETH58

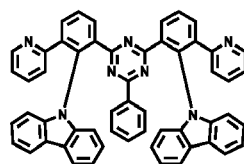


ETH59

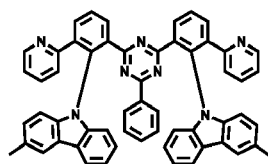


ETH60

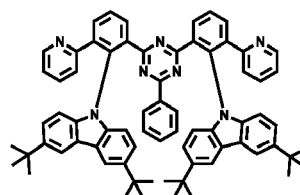
15



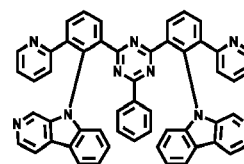
ETH61



ETH62

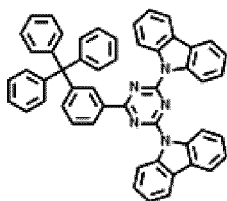


ETH63

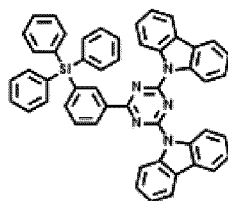


ETH64

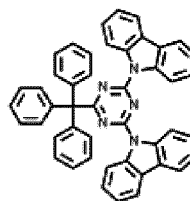
25



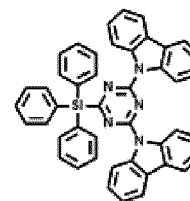
ETH65



ETH66



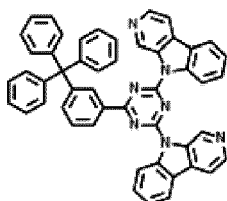
ETH67



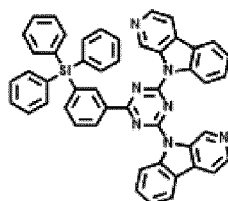
ETH68

30

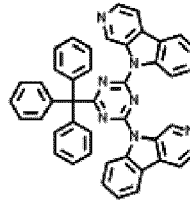
35



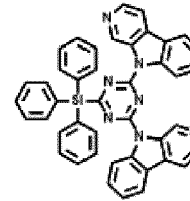
ETH69



ETH70

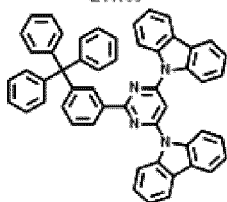


ETH71

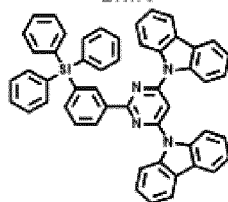


ETH72

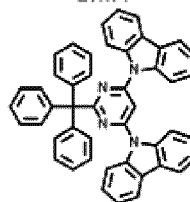
40



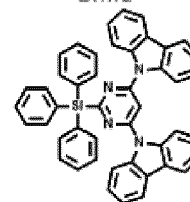
ETH73



ETH74



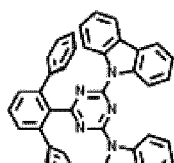
ETH75



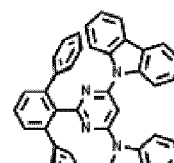
ETH76

45

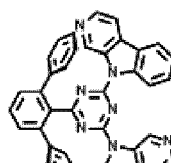
50



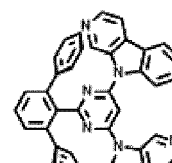
ETH77



ETH78



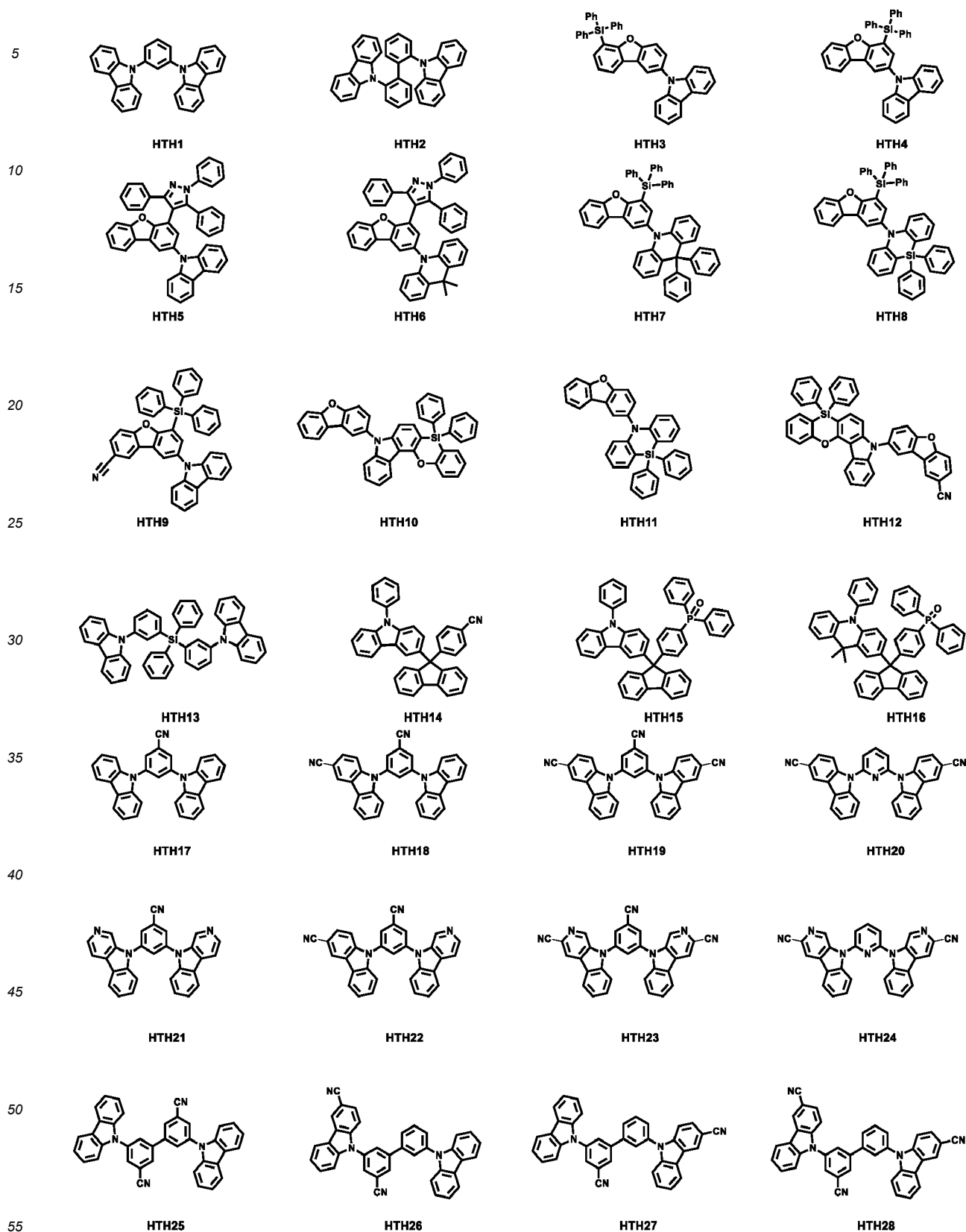
ETH79



ETH80

55

[0085] In one or more embodiments, the third compound may be selected from Compounds HTH1 to HTH28 below:



[0086] In one embodiment, the organic light-emitting device may satisfy at least one of <Condition 1> to <Condition 4> below:

Condition 1

LUMO energy level (eV) of the third compound > LUMO energy level (eV) of the organometallic compound

Condition 2

LUMO energy level (eV) of the organometallic compound > LUMO energy level (eV) of the second compound

Condition 3

HOMO energy level (eV) of the organometallic compound > HOMO energy level (eV) of the third compound

Condition 4

HOMO energy level (eV) of the third compound > HOMO energy level (eV) of the second compound

[0087] The HOMO energy levels and the LUMO energy levels of each of the organometallic compound, the second compound, and the third compound may be negative values, and may be measured according to any suitable method such as, for example, a method described in Evaluation Example 1 in the present specification.

[0088] In one or more embodiments, an absolute value of the difference between the LUMO energy level of the organometallic compound and the LUMO energy level of the second compound may be 0.1 eV or more and 1.0 eV or less, an absolute value of the difference between the LUMO energy level of the organometallic compound and the LUMO energy level of the third compound may be 0.1 eV or more and 1.0 eV or less, an absolute value of the difference between the HOMO energy level of the organometallic compound and the HOMO energy level of the second compound may be 1.25 eV or less (for example, 1.25 eV or less and 0.2 eV or more), an absolute value of the difference between the HOMO energy level of the organometallic compound and the HOMO energy level of the third compound may be 1.25 eV or less (for example, 1.25 eV or less and 0.2 eV or more), and an absolute value of the difference between the HOMO energy level of the organometallic compound and the HOMO energy level of the exciplex formed between the second compound and the third compound may be 1.25 eV or less.

[0089] When the relationships between LUMO energy levels and HOMO energy levels satisfy the conditions as described above, balance between holes and electrons injected into the emission layer may be achieved.

[0090] The emission layer of the organic light-emitting device may include:

1) the organometallic compound represented by Formula 1 (Formula 1 includes a tetradentate ligand and a bidentate ligand, and M in Formula 1 is a transition metal);

2) the second compound represented by Formula 2 (wherein, in Formula 2, a bond between L₅₁ and ring CY₅₁, a bond between L₅₂ and ring CY₅₂, a bond between L₅₃ and ring CY₅₃, a bond between two or more L₅₁(s), a bond between two or more L₅₂(s), a bond between two or more L₅₃(s), a bond between L₅₁ and carbon between X₅₄ and X₅₅ in Formula 2, a bond between L₅₂ and carbon between X₅₄ and X₅₆ in Formula 2, and a bond between L₅₃ and carbon between X₅₅ and X₅₆ in Formula 2 may each be a "carbon-carbon" single bond); and

3) the third compound represented by Formula 3 which is different from Formulae 1 and 2, and accordingly, the exciplex formation between the organometallic compound and either the second compound or the third compound is effectively suppressed or reduced, thereby implementing the organometallic compound having high luminescence efficiency, high color purity, and a long lifespan (e.g., the organic light-emitting device including the organometallic compound in the emission layer may have high luminescence efficiency, high color purity, and a long lifespan).

[0091] The decay time of delayed fluorescence in the time-resolved electroluminescence (TREL) spectrum of the organic light emitting device may be 50 ns or more, for example, 50 ns or more and 2.5 μ s or less. In one embodiment, the decay time of delayed fluorescence in the TREL spectrum of the organic light-emitting device may be 50 ns or more and 2.4 μ s or less, 50 ns or more and 2.3 μ s or less, 50 ns or more and 2.2 μ s or less, 50 ns or more and 2.1 μ s or less, or 50 ns or more and 2 μ s or less. When the decay time of delayed fluorescence of the organic light-emitting device is within these ranges, the time that the organometallic compound remains in an excited state is relatively reduced, so that the organic light-emitting device may have high luminescence efficiency and a long lifespan.

[0092] In one embodiment, the EL spectrum of the organic light-emitting device may have a first peak and a second peak, wherein a maximum emission wavelength of the second peak may be greater than that of the first peak, a difference between the maximum emission wavelength of the second peak and the maximum emission wavelength of the first peak may be 5 nm or more and 10 nm or less, and an intensity of the second peak may be smaller than that of the first peak. When the difference between the maximum emission wavelength of the second peak and the maximum emission wavelength of the first peak is within the range above, the organic light-emitting device has excellent color purity (for example, a blue organic light-emitting device having excellent color purity).

[0093] The maximum emission wavelength of the first peak may be 390 nm or more and 500 nm or less (for example, 430 nm or more and 470 nm or less). In this regard, the organic light-emitting device may emit blue (for example, dark blue) light having excellent color purity.

[0094] The first peak and the second peak may each be an emission peak of phosphorescence emitted from the

organometallic compound.

[0095] The organometallic compound includes a tetradentate ligand and a bidentate ligand, and has an octahedral structure, and accordingly, the exciplex formation between the organometallic compound and either the second compound or the third compound may be suppressed or reduced, thereby achieving high efficiency and high color purity of the organometallic compound (e.g., the organic light-emitting device including the organometallic compound in the emission layer may have high efficiency and high color purity).

[0096] The intensity of the second peak may be 20% to 90% of the intensity of the first peak. When the intensity of each of the second peak and the first peak is within the ranges above, the light emission by the second peak may be suppressed by the organometallic compound while the efficiency of phosphorescence emitted from the first compound is not reduced, thereby implementing the organic light-emitting device having improved color purity.

[0097] Another aspect of an embodiment of the present disclosure provides an organic light-emitting device including:

the first electrode;

the second electrode facing the first electrode; and

the emission layer between the first electrode and the second electrode,

wherein the emission layer includes the organometallic compound, the second compound, and the third compound, the organometallic compound, the second compound, and the third compound are different from each other, the amount of the organometallic compound is smaller than the total amount of the second compound and the third compound,

the organometallic compound is a six-coordinate organometallic compound having an octahedral structure,

the second compound includes at least one group selected from a pyridine group, a pyrimidine group, a pyridazine group, a pyrazine group, a triazine group, and a tetrazine group, and

the organometallic compound and either the second compound or the third compound does not form an exciplex.

[0098] In addition, the decay time of delayed fluorescence in the TREL spectrum of the organic light-emitting device may be 50 ns or more (for example, 50 ns or more and 2.5 μ s or less, in one embodiment, 50 ns or more and 2.4 μ s or less, 50 ns or more and 2.3 μ s or less, 50 ns or more and 2.2 μ s or less, 50 ns or more and 2.1 μ s or less, or 50 ns or more and 2 μ s or less). When the decay time of delayed fluorescence of the organic light-emitting device is within these ranges, the time that the organometallic compound remains in an excited state is relatively reduced, so that the organic light-emitting device may have high luminescent efficiency and a long lifespan.

[0099] The organometallic compound, the second compound, and the third compound may each be the same as described above.

[0100] Another aspect of an embodiment of the present disclosure provides an electronic apparatus including the organic light-emitting device. The electronic apparatus may further include a thin-film transistor. For example, the electronic apparatus may further include a thin-film transistor including a source electrode and a drain electrode, wherein the first electrode of the organic light-emitting device is electrically coupled to the source electrode or the drain electrode.

Description of FIG. 1

[0101] FIG. 1 is a schematic cross-sectional 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.

[0102] 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

[0103] In FIG. 1, a substrate may be additionally located under the first electrode 110 or above the second electrode 190. The substrate may be a glass substrate and/or a plastic substrate, each having excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and/or water resistance.

[0104] The first electrode 110 may be formed by, for example, depositing or sputtering a material for forming the first electrode 110 on the substrate. When the first electrode 110 is an anode, the material for forming the first electrode 110 may be selected from materials having a high work function to facilitate hole injection.

[0105] 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, the material for forming the first electrode 110 may be selected from indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO_2), zinc oxide (ZnO), and any combination 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, the material for forming the first electrode 110 may be selected from magnesium (Mg), silver (Ag), aluminium (Al), aluminium-lithium (Al-Li), calcium (Ca), magnesium-indium

(Mg-In), magnesium-silver (Mg-Ag), and any combination thereof, but embodiments of the present disclosure are not limited thereto.

[0106] 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

[0107] The organic layer 150 is located on the first electrode 110. The organic layer 150 may include the emission layer.

[0108] The organic layer 150 may 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.

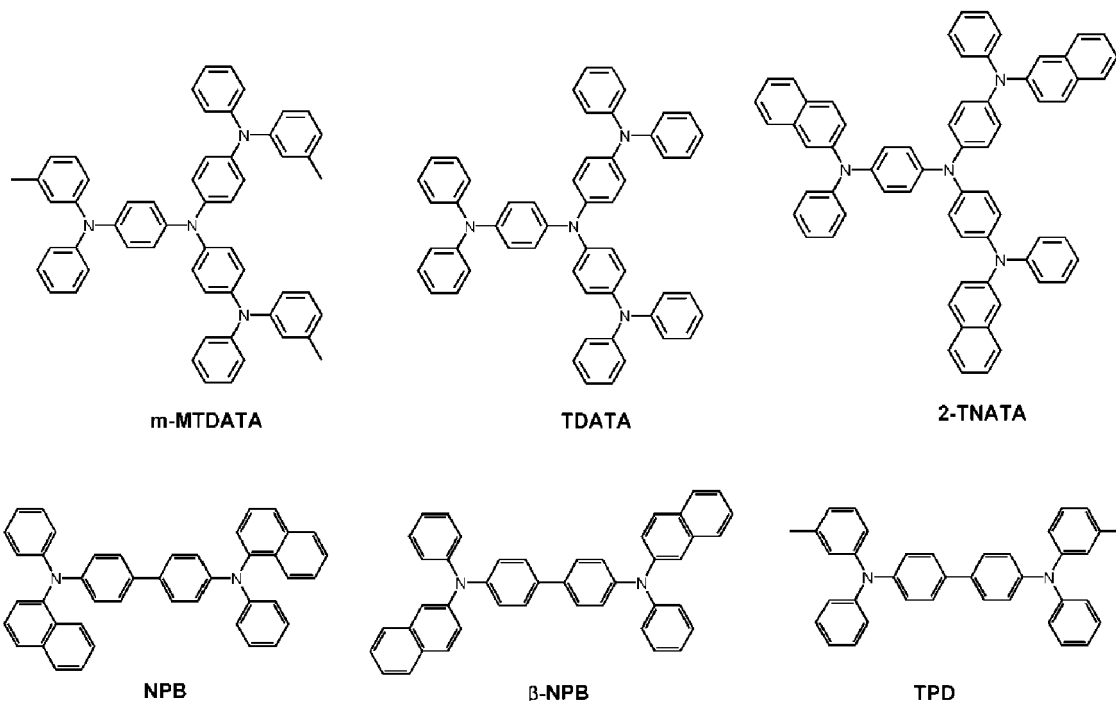
Hole transport region in organic layer 150

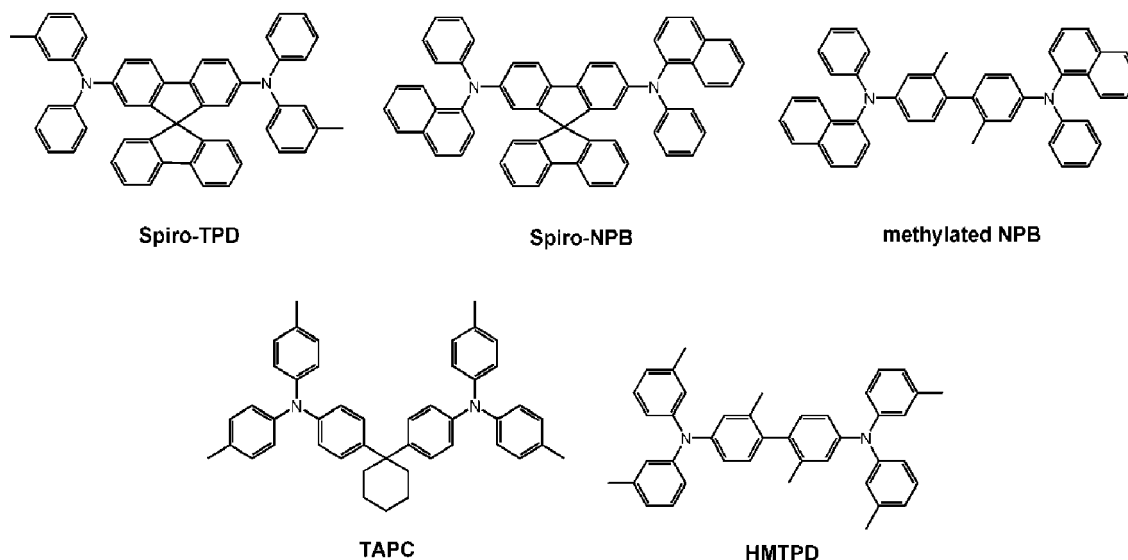
[0109] The hole transport region may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

[0110] 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.

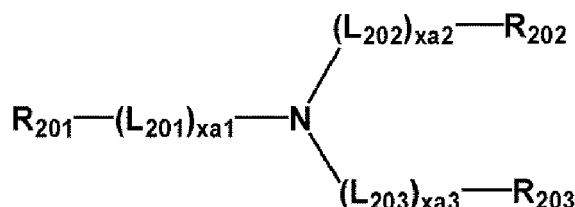
[0111] For example, the hole transport region may have a single-layered structure including a single layer including a plurality of different materials, or a multi-layered structure having a hole injection layer/hole transport layer structure, a hole injection layer/hole transport layer/emission auxiliary layer structure, a hole injection layer/emission auxiliary layer structure, a hole transport layer/emission auxiliary layer structure, or a hole injection layer/hole transport layer/electron blocking layer structure, wherein for each structure, constituting layers are sequentially stacked from the first electrode 110 in this stated order, but the structure of the hole transport region is not limited thereto.

[0112] 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, HMTDP, 4,4',4"-tris(N-carbazolyl)triphenylamine (TCTA), polyaniline/dodecylbenzenesulfonic acid (PANI/DBSA), poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate) (PEDOT/PSS), polyaniline/camphor sulfonic acid (PANI/CSA), polyaniline/poly(4-styrenesulfonate) (PANI/PSS), a compound represented by Formula 201 below, and a compound represented by Formula 202 below:

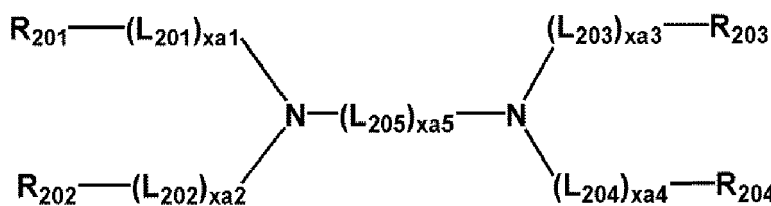




Formula 201



Formula 202



[0113] In Formulae 201 and 202,

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_{18} cycloalkenylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6 - C_{60} (e.g. C_6 - C_{32}) arylene group, a substituted or unsubstituted C_1 - C_{60} (e.g. C_1 - C_{20}) heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

L_{205} may be selected from $-O-$, $-S-$, $-N(Q_{201})-$, a substituted or unsubstituted C_1 - C_{20} alkylene group, a substituted or unsubstituted C_2 - C_{20} alkenylene group, a substituted or unsubstituted C_3 - C_{10} cycloalkylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3 - C_{10} cycloalkenylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6 - C_{60} (e.g. C_6 - C_{32}) arylene group, a substituted or unsubstituted C_1 - C_{60} (e.g. C_1 - C_{20}) heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

$xa1$ to $xa4$ may each independently be an integer from 0 to 3,

$xa5$ may be an integer from 1 to 10, and

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_{18} cycloalkenyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6 - C_{60} (e.g. C_6 - C_{32}) aryl group, a substituted or unsubstituted C_6 - C_{60} (e.g. C_6 - C_{32}) aryloxy group, a substituted or unsubstituted C_6 - C_{60} (e.g. C_6 - C_{32}) arylthio group, a substituted or unsubstituted C_1 - C_{60} (e.g. C_1 - C_{20}) heteroaryl group, a substituted or unsubstituted

monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group.

[0114] For example, in Formula 202, R_{201} and R_{202} may optionally be linked to each other via a single bond, a dimethyl-methylene group, or a diphenyl-methylene group, and R_{203} and R_{204} may optionally be linked to each other via a single

[0115] In one embodiment, in Formulae 201 and 202,

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

a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylenylene group, a heptalenylene group, an indacenylene group, an acenaphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylene group, a pentacenylene group, a rubicenylene group, a coronenylene group, an ovalenylene group, a thiophenylene group, a furanylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, and a pyridinylenylene group; and

a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylenylene group, a heptalenylene group, an indacenylene group, an acenaphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylene group, a pentacenylene group, a rubicenylene group, a coronenylene group, an ovalenylene group, a thiophenylene group, a furanylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene 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 C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1 - C_{10} alkyl group, a phenyl group substituted with -F, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, $-Si(Q_{31})(Q_{32})(Q_{33})$, and $-N(Q_{31})(Q_{32})$, and

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

[0116] In one or more embodiments, xa_1 to xa_4 may each independently be 0, 1, or 2.

[0117] In one or more embodiments, xa_5 may be 1, 2, 3, or 4.

[0118] In one or more embodiments, R_{201} to R_{204} and Q_{201} may each independently be selected from: a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group; and

a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group, each substituted with at least one

selected from deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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 hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, -Si(Q₃₁)(Q₃₂)(Q₃₃), and -N(Q₃₁)(Q₃₂), and

Q₃₁ to Q₃₃ may each be the same as described above.

[0119] In one or more embodiments, at least one selected from R₂₀₁ to R₂₀₃ in Formula 201 may each independently be selected from:

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

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.

[0120] In one or more embodiments, in Formula 202, i) R₂₀₁ and R₂₀₂ may be linked to each other via a single bond, and/or ii) R₂₀₃ and R₂₀₄ may be linked to each other via a single bond.

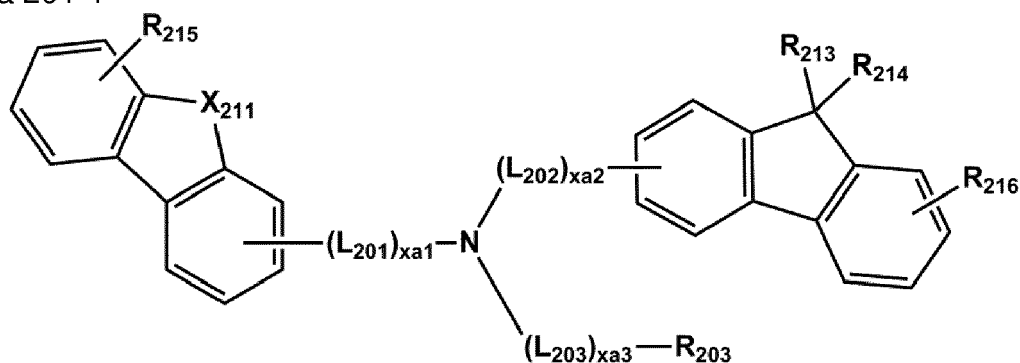
[0121] In one or more embodiments, at least one of R₂₀₁ to R₂₀₄ in Formula 202 may be selected from:

a carbazolyl group; and

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.

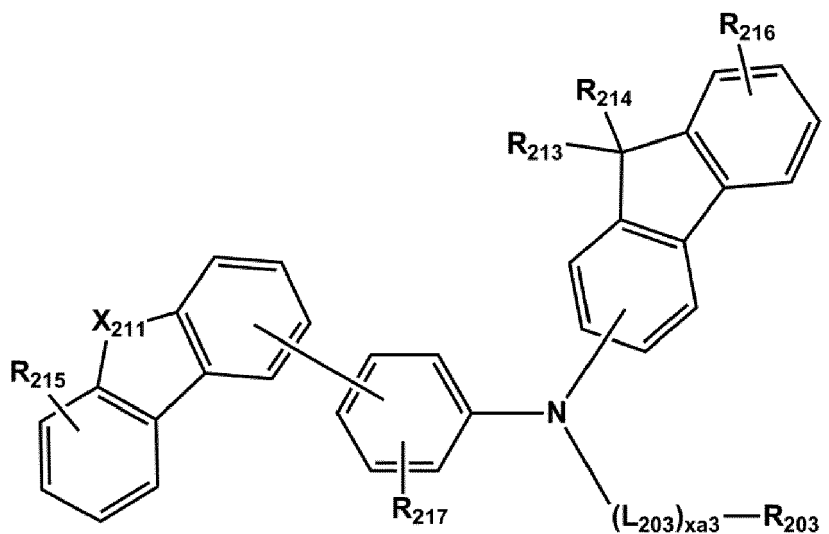
[0122] The compound represented by Formula 201 may be represented by Formula 201-1 below:

Formula 201-1



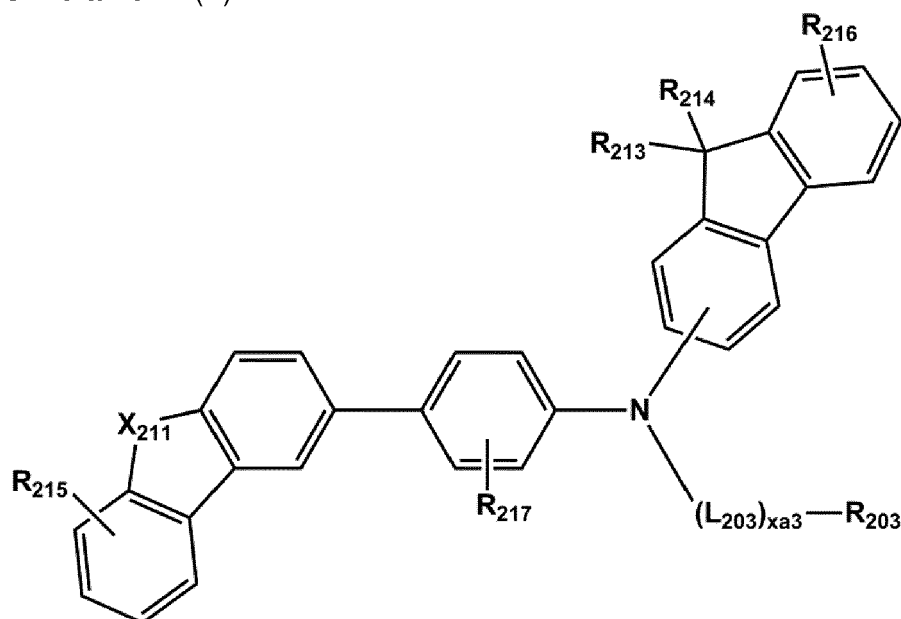
[0123] In one embodiment, the compound represented by Formula 201 may be represented by Formula 201-2 below, but embodiments of the present disclosure are not limited thereto:

Formula 201-2



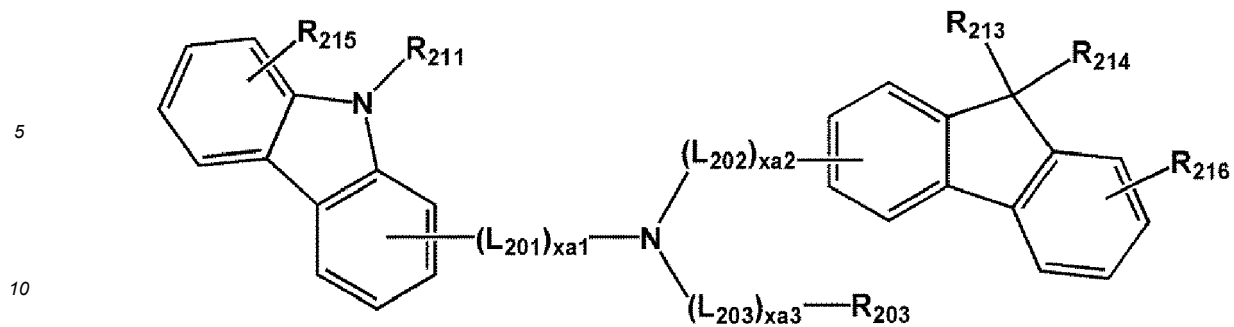
[0124] In one or more embodiments, the compound represented by Formula 201 may be represented by Formula 201-2(1) below, but embodiments of the present disclosure are not limited thereto:

Formula 201-2(1)



[0125] In one or more embodiments, the compound represented by Formula 201 may be represented by Formula 201A below:

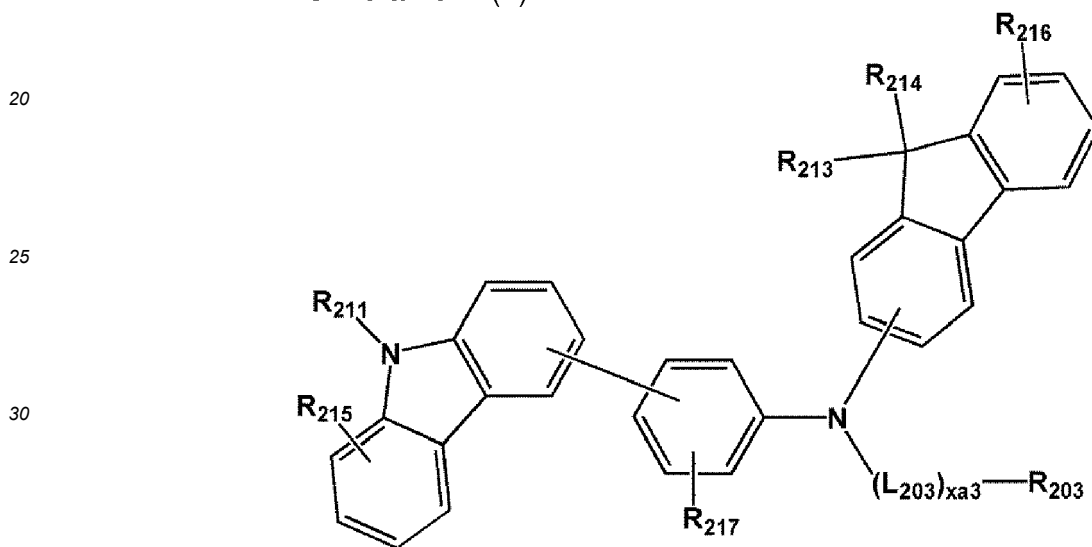
Formula 201A



15

[0126] In one or more embodiments, the compound represented by Formula 201 may be represented by Formula 201A(1) below, but embodiments of the present disclosure are not limited thereto:

Formula 201A(1)



40

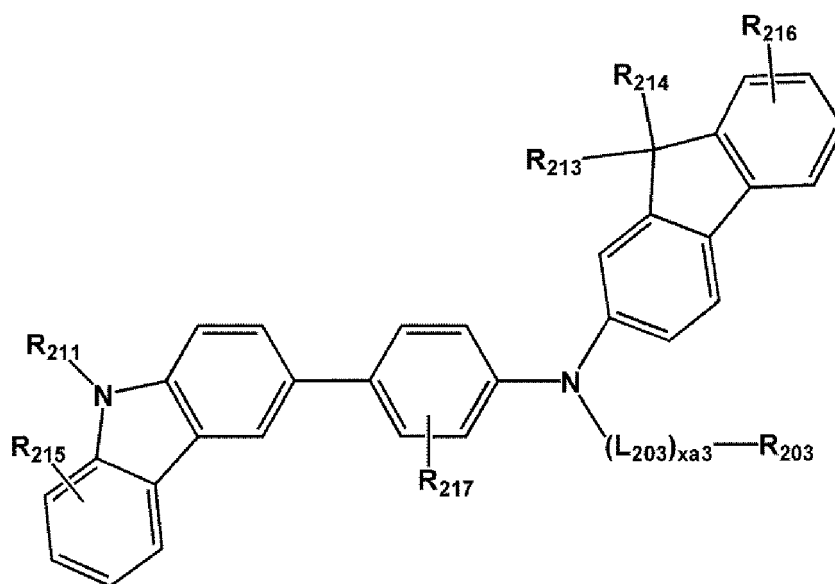
[0127] In one or more embodiments, the compound represented by Formula 201 may be represented by Formula 201A-1 below, but embodiments of the present disclosure are not limited thereto:

Formula 201A-1

45

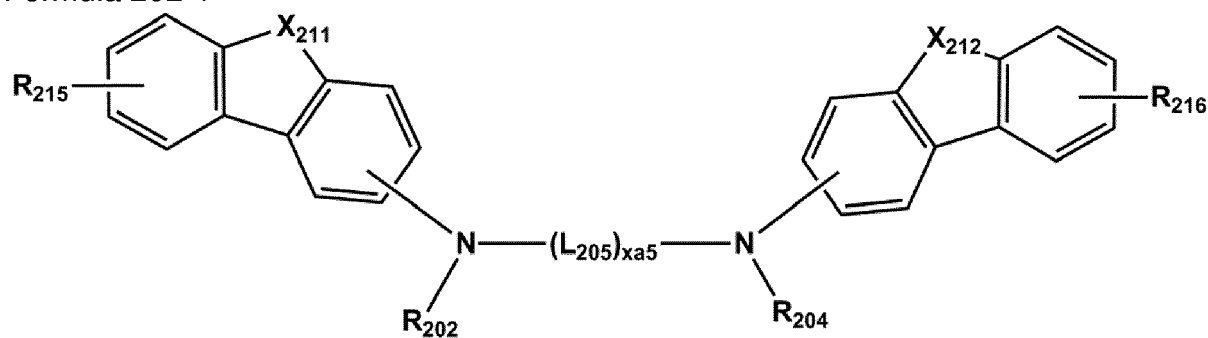
50

55



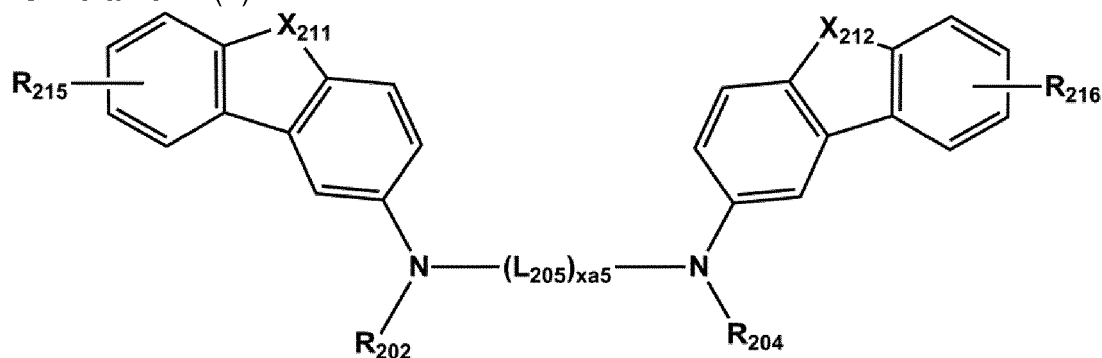
[0128] In one embodiment, the compound represented by Formula 202 may be represented by Formula 202-1 below:

Formula 202-1



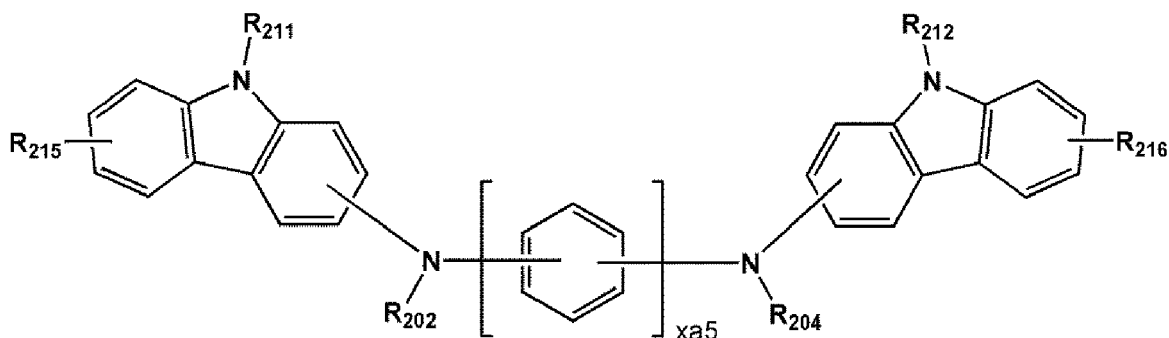
[0129] In one or more embodiments, the compound represented by Formula 202 may be represented by Formula 202-1 (1) below:

Formula 202-1(1)



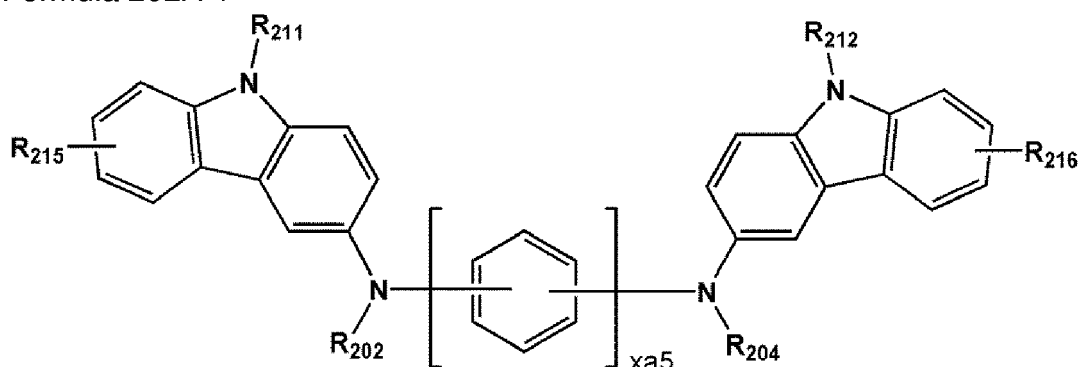
[0130] In one or more embodiments, the compound represented by Formula 202 may be represented by Formula 202A below:

Formula 202A



[0131] In one or more embodiments, the compound represented by Formula 202 may be represented by Formula 202A-1 below:

Formula 202A-1



[0132] In Formulae 201-1, 201-2, 201-2(1), 201A, 201A(1), 201A-1, 202-1, 202-1(1), 202A, and 202A-1, L_{201} to L_{203} , $xa1$ to $xa3$, $xa5$, and R_{202} to R_{204} may each be the same as described above,

L_{205} may be selected from a phenylene group and a fluorenylene group,

X_{211} may be selected from O, S, and N(R_{211}),

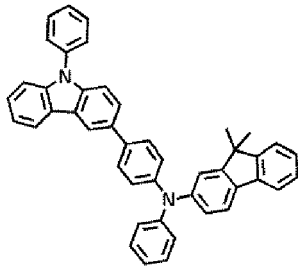
X_{212} may be selected from O, S, and N(R_{212}),

R_{211} and R_{212} may each be the same as described in connection with R_{203} , and

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 fluoranthrenyl 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.

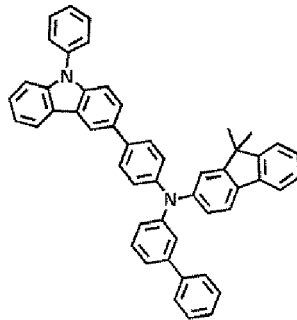
[0133] The hole transport region may include at least one compound selected from Compounds HT1 to HT48 below, but embodiments of the present disclosure are not limited thereto:

5

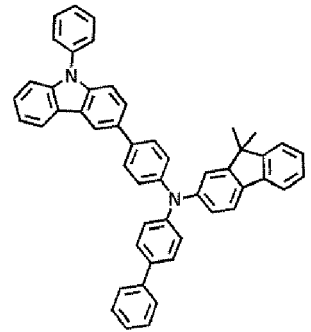


HT1

10

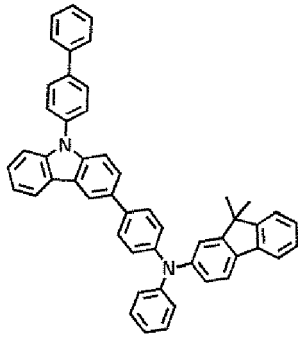


HT2



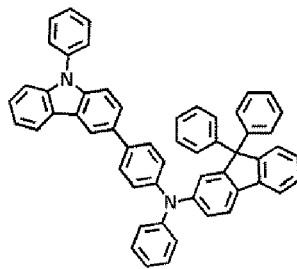
HT3

15

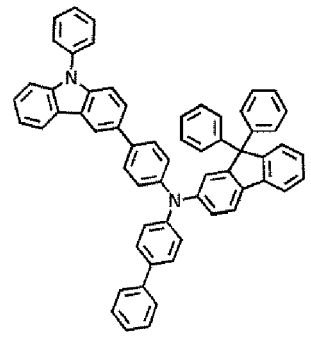


HT4

20

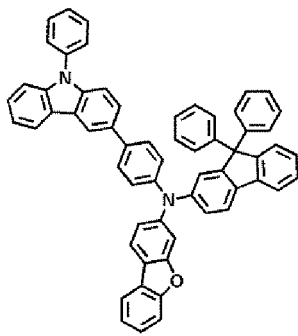


HT5



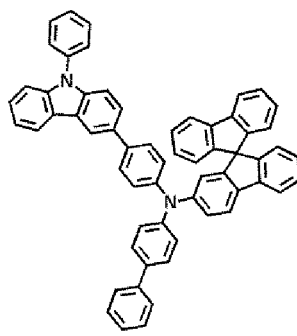
HT6

25

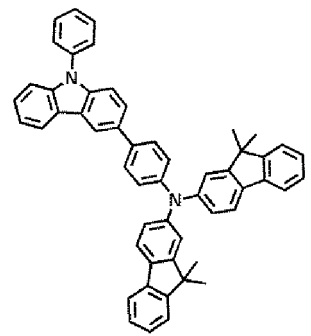


HT7

30

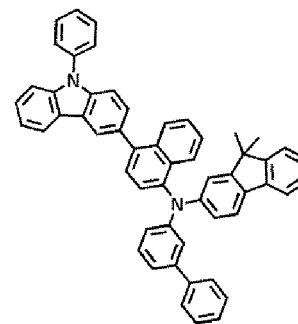


HT8



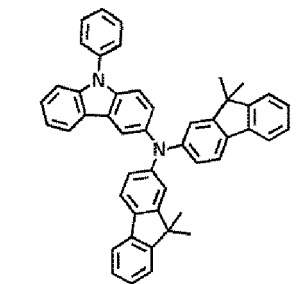
HT9

35

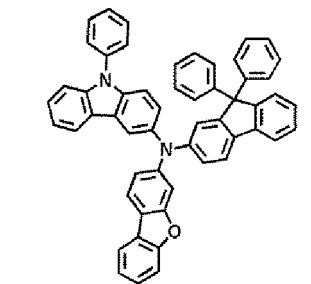


HT10

40



HT11

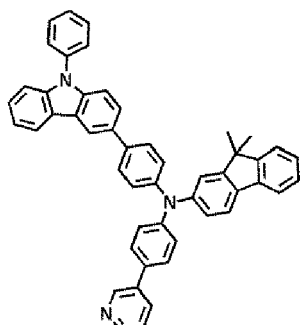


HT12

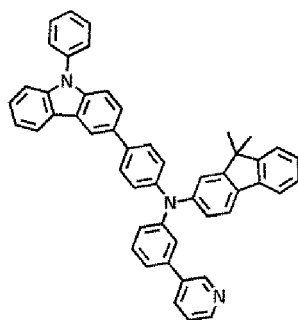
45

50

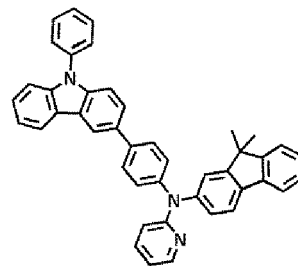
55



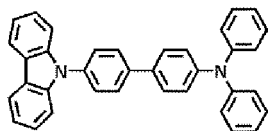
HT13



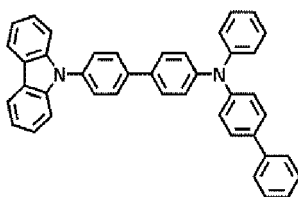
HT14



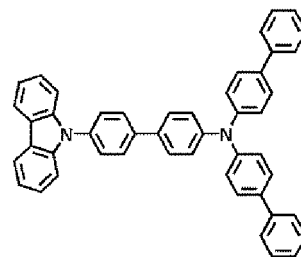
HT15



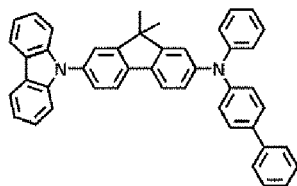
HT16



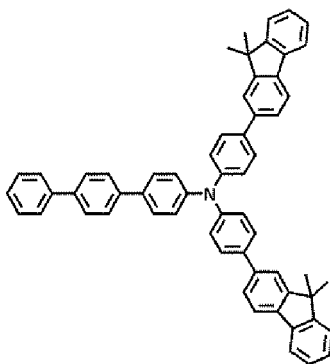
HT17



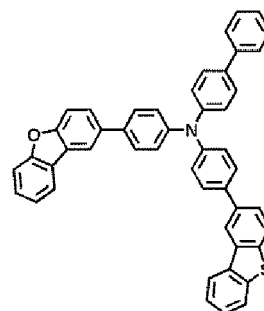
HT18



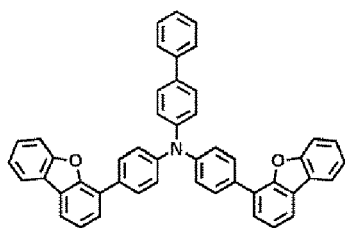
HT19



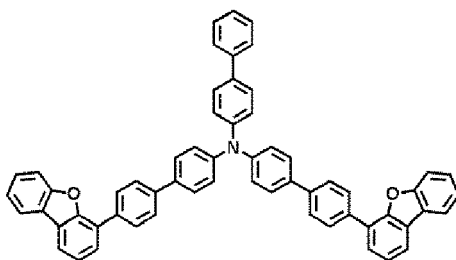
HT20



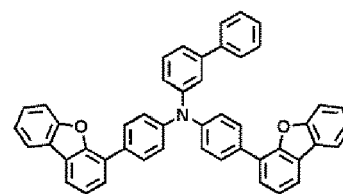
HT21



HT22

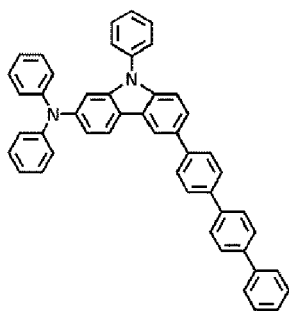


HT23



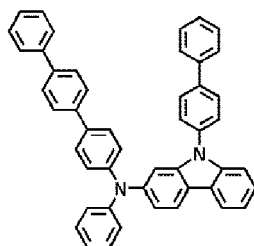
HT24

5

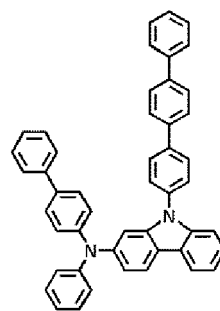


HT25

10

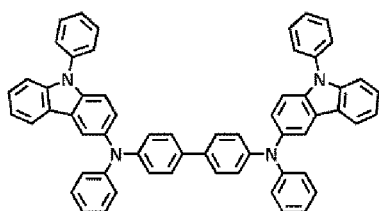


HT26



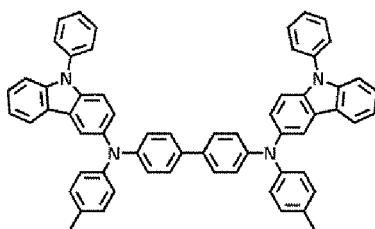
HT27

15

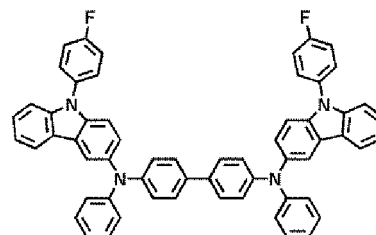


HT28

20

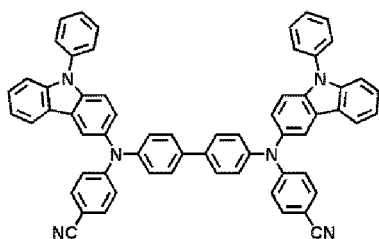


HT29



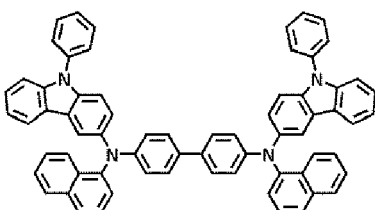
HT30

25

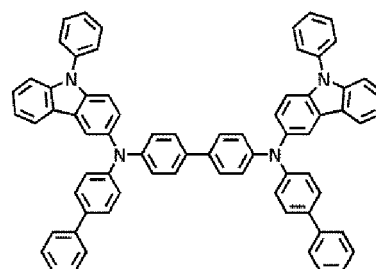


HT31

30

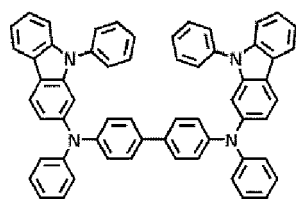


HT32



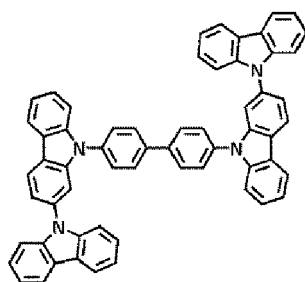
HT33

35



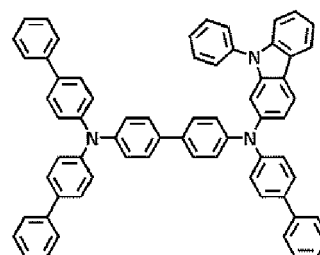
HT34

40



HT35

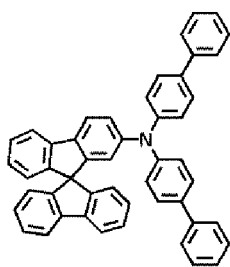
45



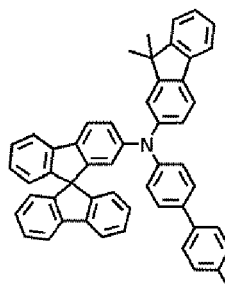
HT36

50

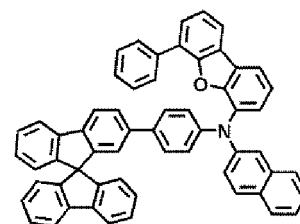
55



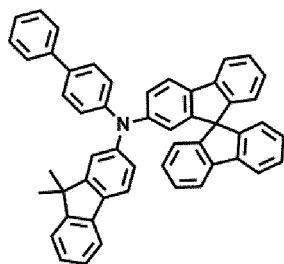
HT37



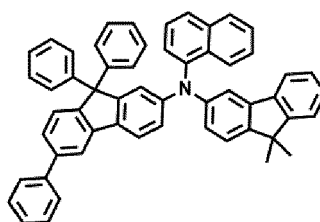
HT38



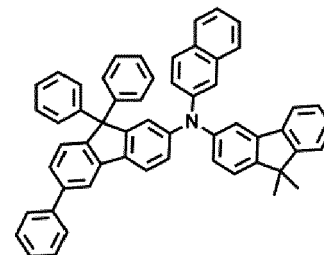
HT39



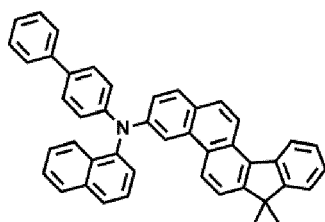
HT40



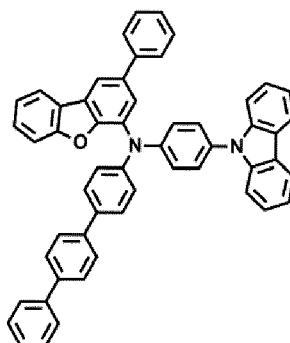
HT41



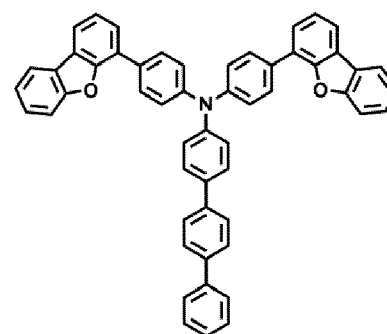
HT42



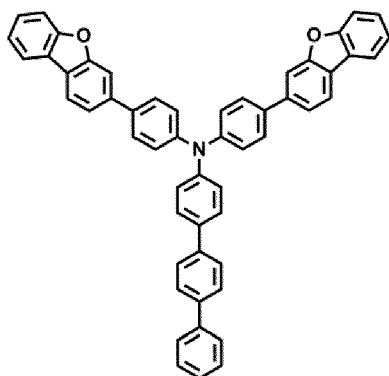
HT43



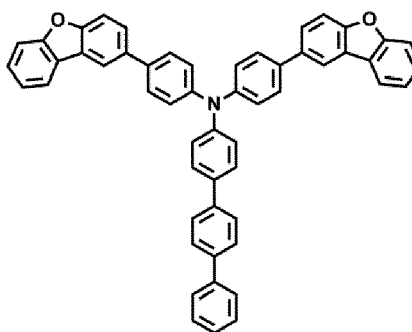
HT44



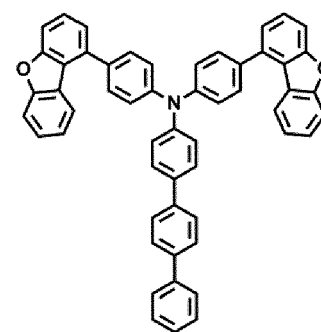
HT45



HT46



HT47



HT48

[0134] 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 7,000 Å, about 100 Å to about 5,000 Å, or about 100 Å to about 1,000 Å. When the hole transport region includes at least one selected from a hole injection layer and a hole transport layer, the thickness of the hole injection

layer may be in a range of about 100 Å to about 9,000 Å, for example, about 100 Å to about 7,000 Å, about 100 Å to about 5,000 Å, about 100 Å to about 3,000 Å, about 100 Å to about 2,000 Å, about 100 Å to about 1,000 Å or about 500 Å to about 700 Å, and the thickness of the hole transport layer may be in a range of about 50 Å to about 2,000 Å, for example, about 100 Å to about 1,500 Å or about 200 Å to about 400 Å. When the thicknesses of the hole transport region, the hole injection layer and the hole transport layer are within these ranges, suitable or satisfactory hole transporting characteristics may be obtained without a substantial increase in driving voltage.

[0135] 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 or reduce 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

[0136] 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.

[0137] The charge-generation material may be, for example, a p-dopant.

[0138] In one embodiment, a lowest unoccupied molecular orbital (LUMO) energy level of the p-dopant may be -3.5 eV or less.

[0139] 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.

[0140] In one embodiment, the p-dopant may include at least one selected from:

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

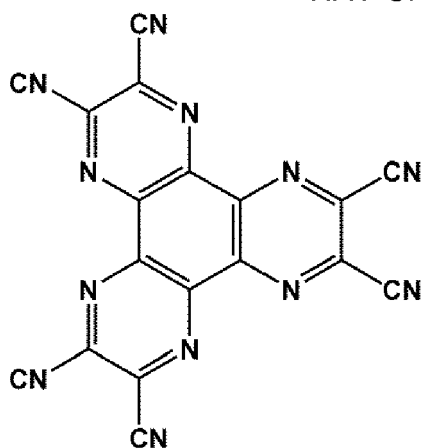
a metal oxide, such as tungsten oxide or molybdenum oxide;

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

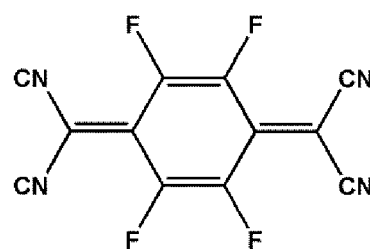
a compound represented by Formula 221 below,

but embodiments of the present disclosure are not limited thereto:

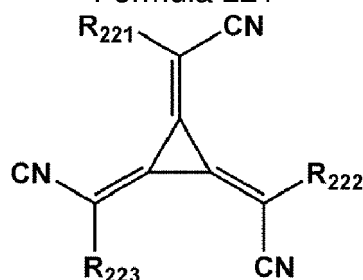
HAT-CN



F4-TCNQ



Formula 221



[0141] In Formula 221,

R₂₂₁ to R₂₂₃ 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 (e.g. C₆-C₃₂) aryl group, a substituted or unsubstituted C₁-C₆₀ (e.g. C₁-C₂₀) heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, and at least one selected from R₂₂₁ to R₂₂₃ may have at least one substituent selected from a cyano group, -F, -Cl, -Br, -I, a C₁-C₂₀ alkyl group substituted with -F, a C₁-C₂₀ alkyl group substituted with -Cl, a C₁-C₂₀ alkyl group substituted with -Br, and a C₁-C₂₀ alkyl group substituted with -I.

Emission layer in organic layer 150

[0142] 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. Here, the blue emission layer may include the organometallic compound.

[0143] 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 (e.g., physically 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. Here, the blue light-emitting material may include the organometallic compound.

[0144] In addition, the organic light-emitting device 10 may include the organic layer 150 including the emission layers in the number of p. Here, p may be an integer of 2 or more, and the emission layers in the number of p may have a structure in which the emission layers are in contact (e.g., physical contact) with each other or are spaced apart from each other. Each of two or more emission layers in the number of p may include the organometallic compound.

[0145] In addition, the emission layer may include a first emission layer, a second emission layer, and a third emission layer, wherein the first emission layer may emit first-color light, the second emission layer may emit second-color light, and the third emission layer may emit third-color light. The first-color light, the second-color light, and the third-color light may each have a different maximum emission wavelength from each other. The first-color light may be blue, the second-color light may be green, the third-color light may be red, and the first emission layer may include the organometallic compound represented by Formula 1.

[0146] The emission layer may include a host and a dopant. The dopant may include the organometallic compound represented by Formula 1. The host may include at least one of the second compound and the third compound. The second compound and the third compound may each be the same as described elsewhere in the present specification.

[0147] An amount of a dopant in the emission layer may be, based on about 100 parts by weight of the host, in the range of about 0.01 parts by weight to about 15 parts by weight, but embodiments of the present disclosure are not limited thereto.

[0148] A thickness of the emission layer may be in a range of about 100 Å to about 1,000 Å, for example, about 100 Å to about 800 Å, about 150 Å to about 800 Å, about 150 Å to about 700 Å, about 150 Å to about 650 Å, about 200 Å to about 600 Å or about 200 Å to about 400 Å. When the thickness of the emission layer is within this range, excellent light-emission characteristics may be obtained without a substantial increase in driving voltage.

Electron transport region in organic layer 150

[0149] 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.

[0150] 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.

[0151] 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.

[0152] The electron transport region may include the second compound as described above.

[0153] In one embodiment, the electron transport region may include a buffer layer, the buffer layer is in direct contact (e.g., physical contact) with the emission layer, and the buffer layer may include the second compound as described above.

[0154] In one or more embodiments, the electron transport region may include a buffer layer, an electron transport layer, and an electron injection layer stacked in this order from the emission layer, and the buffer layer may include the second compound as described above.

[0155] The electron transport region (for example, 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.

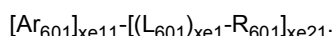
[0156] The term " π electron-depleted nitrogen-containing ring," as used herein, indicates a C_1 - C_{60} (e.g. a C_1 - C_{30}) heterocyclic group having at least one $*-N=*$ moiety as a ring-forming moiety.

[0157] For example, the " π electron-depleted nitrogen-containing ring" may be i) a 5-membered to 7-membered heteromonocyclic group having at least one $*-N=*$ moiety, ii) a heteropolycyclic group in which two or more 5-membered to 7-membered heteromonocyclic groups each having at least one $*-N=*$ moiety are condensed with each other (e.g., combined together), 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 (e.g., combined with) at least one C_5 - C_{60} (e.g. a C_5 - C_{30}) carbocyclic group.

[0158] Examples of the π electron-deficient nitrogen-containing ring include an imidazole ring, a pyrazole ring, a thiazole ring, an isothiazole ring, an oxazole ring, an isoxazole ring, a pyridine ring, a pyrazine ring, a pyrimidine ring, a pyridazine ring, an indazole ring, a purine ring, a quinoline ring, an isoquinoline ring, a benzoquinoline ring, a phthalazine ring, a naphthyridine ring, a quinoxaline ring, a quinazoline ring, a cinnoline ring, a phenanthridine ring, an acridine ring, a phenanthroline ring, a phenazine ring, a benzimidazole ring, a benzoisothiazole ring, a benzoxazole ring, an benzooxazole ring, a triazole ring, a tetrazole ring, an oxadiazole ring, a triazine ring, a thiadiazole ring, an imidazopyridine ring, an imidazopyrimidine ring, and an azacarbazole ring, but are not limited thereto.

[0159] For example, the electron transport region may include a compound represented by Formula 601 below:

Formula 601



[0160] In Formula 601,

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,

$xe11$ may be 1, 2, or 3,

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 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,

$xe1$ may be an integer from 0 to 5,

R_{601} may be selected from a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6 - C_{60} aryl group, a substituted or unsubstituted C_6 - C_{60} aryloxy group, a substituted or unsubstituted C_6 - C_{60} arylthio group, a substituted or unsubstituted C_1 - C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, -Si(Q_{601})(Q_{602})(Q_{603}), -C(=O)(Q_{601}), -S(=O)₂(Q_{601}), and -P(=O)(Q_{601})(Q_{602}).

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

$xe21$ may be an integer from 1 to 5.

[0161] In one embodiment, at least one of $Ar_{601}(s)$ in the number of $xe11$ and $R_{601}(s)$ in the number of $xe21$ may include the π electron-deficient nitrogen-containing ring.

[0162] For example, Ar_{601} may be a substituted or unsubstituted C_5 - C_{30} carbocyclic group or a substituted or unsubstituted C_1 - C_{20} heterocyclic group, but embodiments are not limited thereto.

[0163] In one embodiment, Ar_{601} in Formula 601 may be selected from:

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

quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, a phenanthroline group, a phenazine group, a benzimidazole group, an isobenzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a thiadiazole group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group; and

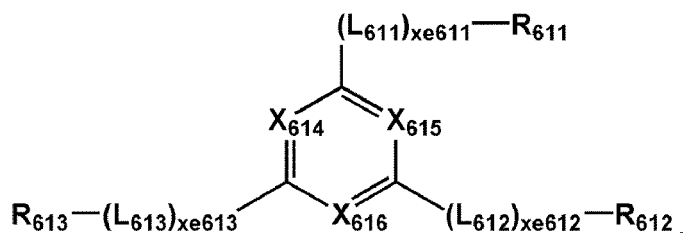
a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, 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 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.

[0164] When xe11 in Formula 601 is 2 or more, two or more Ar₆₀₁(s) may be linked to each other via a single bond.

[0165] In one or more embodiments, Ar₆₀₁ in Formula 601 may be an anthracene group.

[0166] In one or more embodiments, the compound represented by Formula 601 may be represented by Formula 601-1 below:

Formula 601-1



[0167] In Formula 601-1,

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 of X₆₁₄ to X₆₁₆ may be N, L₆₁₁ to L₆₁₃ may each independently be the same as described in connection with L₆₀₁,

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

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

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.

[0168] For example, L₆₀₁ and L₆₁₁ to L₆₁₃ in Formulae 601 and 601-1 may each independently be selected from: a substituted or unsubstituted C₃-C₁₀ cycloalkylene group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkylene group, a substituted or unsubstituted C₃-C₁₀ cycloalkenylene group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenylene group, a substituted or unsubstituted C₆-C₃₀ arylene group, a substituted or unsubstituted C₁-C₂₀ heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group, but embodiments are not limited thereto.

[0169] In one embodiment, L₆₀₁ and L₆₁₁ to L₆₁₃ in Formulae 601 and 601-1 may each independently be selected from:

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 dibenzofuranylenylene group, a dibenzothiophenylenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a

dibenzosilolylene group, a pyridinylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isoxazolylene group, a thiadiazolylene group, an oxadiazolylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolylene group; and

a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylene group, a pentacenylene group, a thiophenylenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylenylene group, a dibenzofuranylene group, a dibenzothiophenylenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, a pyridinylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isoxazolylene group, a thiadiazolylene group, an oxadiazolylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolylene group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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, and an azacarbazolyl group, but embodiments of the present disclosure are not limited thereto.

[0170] In one or more embodiments, xe1 and xe611 to xe613 in Formulae 601 and 601-1 may each independently be 0, 1, or 2.

[0171] For example, R₆₀₁ and R₆₁₁ to R₆₁₃ in Formulae 601 and 601-1 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-C₃₀ aryl group, a substituted or unsubstituted C₆-C₃₀ aryloxy group, a substituted or unsubstituted C₆-C₃₀ arylthio group, a substituted or unsubstituted C₁-C₂₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, -Si(Q₆₀₁)(Q₆₀₂)(Q₆₀₃), -C(=O)(Q₆₀₁), -S(=O)₂(Q₆₀₁), and -P(=O)(Q₆₀₁)(Q₆₀₂).

[0172] In one or more embodiments, R₆₀₁ and R₆₁₁ to R₆₁₃ in Formulae 601 and 601-1 may each independently be selected from:

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group,

an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacar-

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

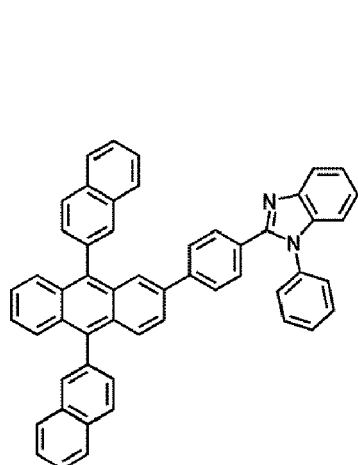
bazolyl group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl 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, and an azacar-

bazolyl group; and

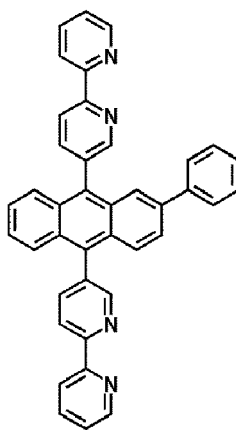
-S(=O)₂(Q₆₀₁) and -P(=O)(Q₆₀₁)(Q₆₀₂), and

Q₆₀₁ and Q₆₀₂ may each be the same as described above.

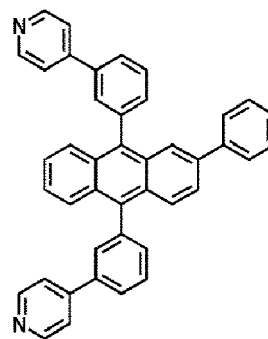
[0173] The electron transport region may include at least one compound selected from Compounds ET1 to ET36 below, but embodiments of the present disclosure are not limited thereto:



ET1

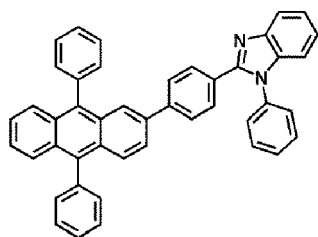


ET2



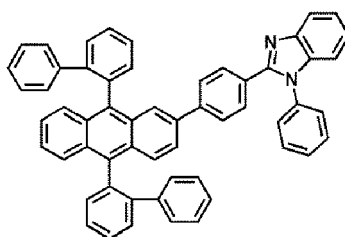
ET3

5

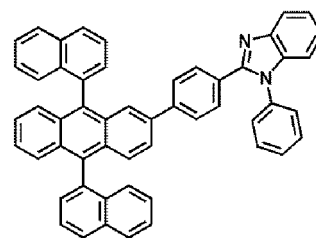


ET4

10

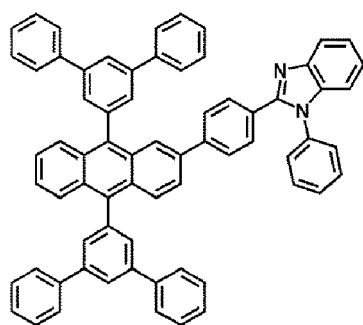


ET5



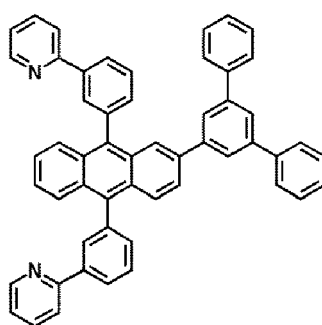
ET6

15



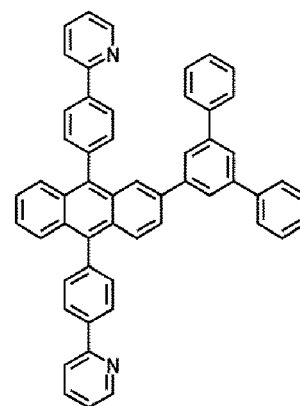
ET7

20



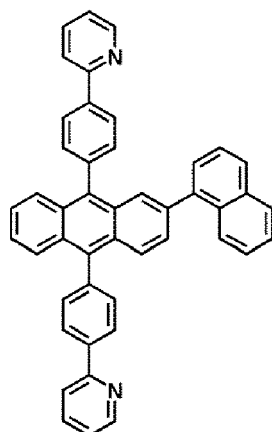
ET8

25



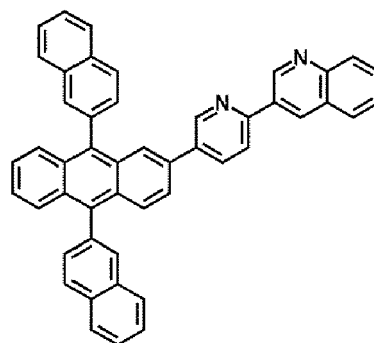
ET9

30



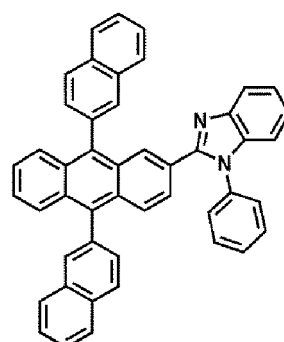
ET10

35



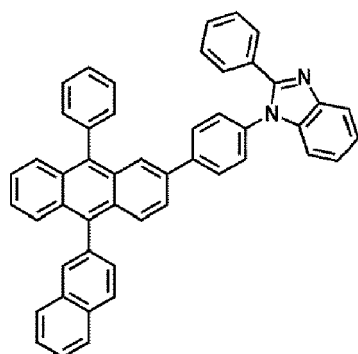
ET11

40



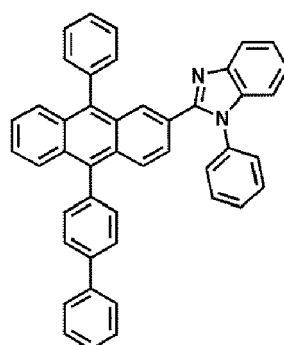
ET12

45



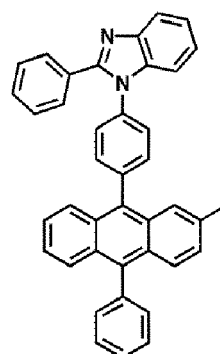
ET13

50



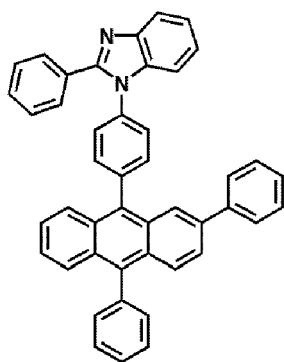
ET14

55



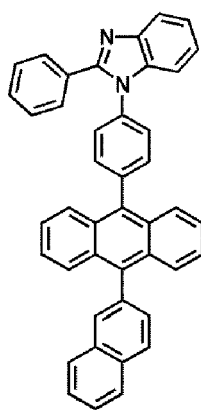
ET15

5



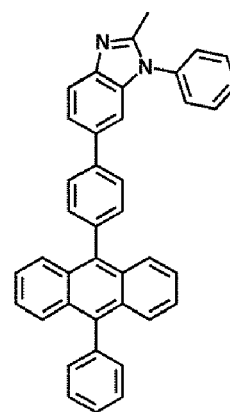
ET16

10



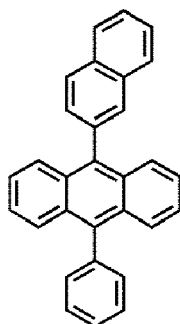
ET17

15



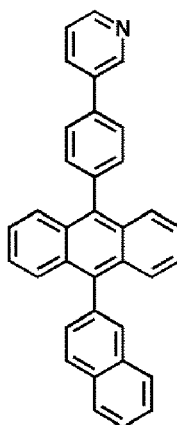
ET18

20



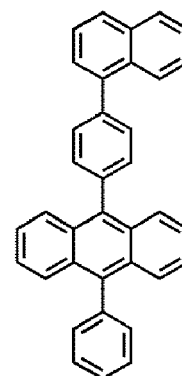
ET19

25



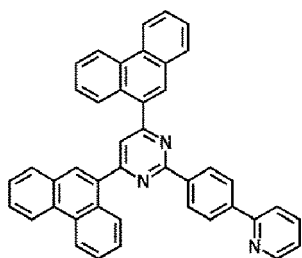
ET20

30



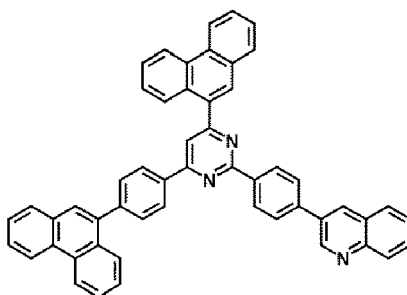
ET21

35



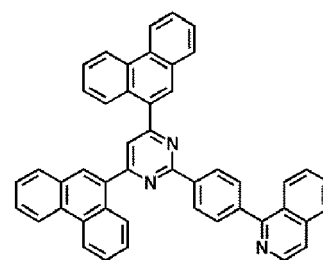
ET22

40



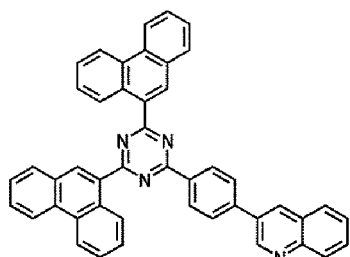
ET23

45



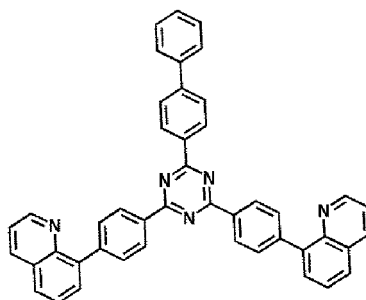
ET24

50

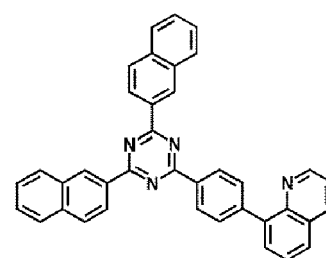


ET25

55



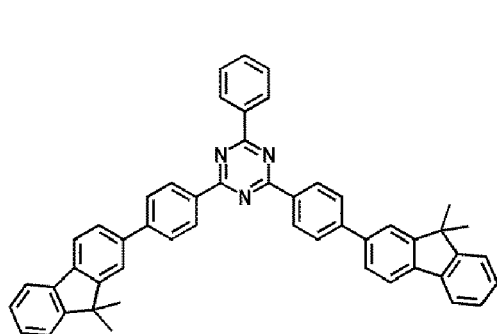
ET26



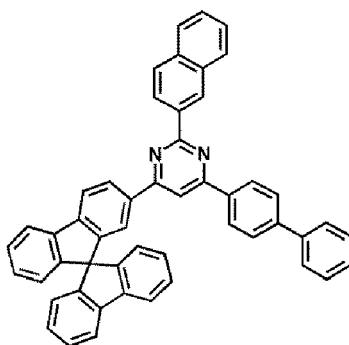
ET27

5

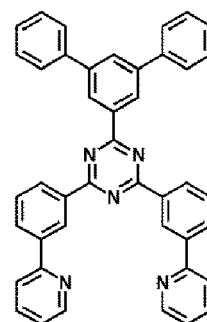
10



ET28



ET29

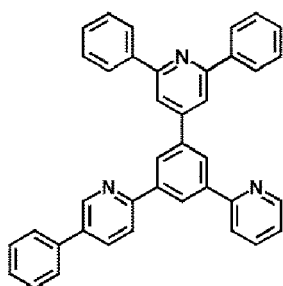


ET30

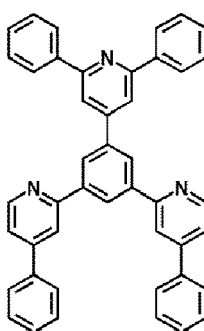
15

20

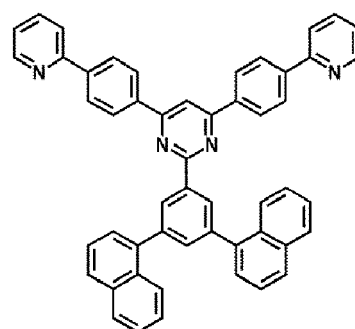
25



ET31



ET32

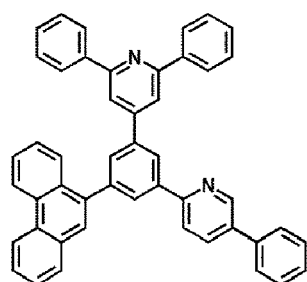


ET33

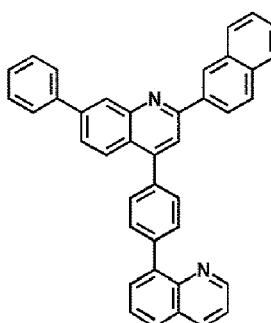
30

35

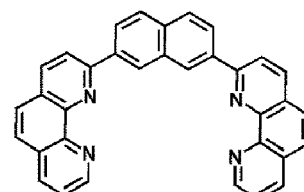
40



ET34



ET35

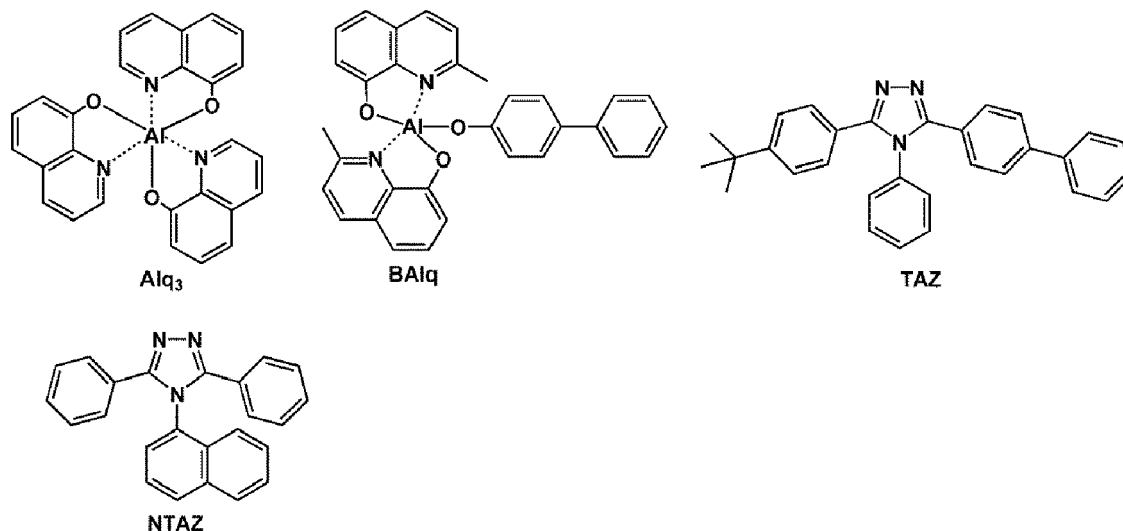


ET36

[0174] In one or more embodiments, the electron transport region may include at least one selected from 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP), 4,7-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:

50

55



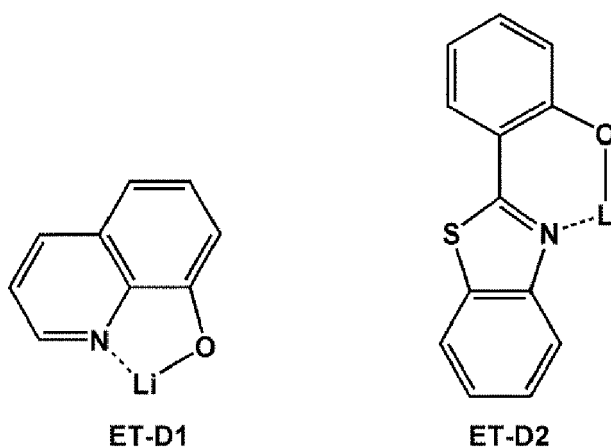
[0175] Thicknesses of the buffer layer, the hole blocking layer, and the electron control layer may each independently be in a range of about 20 Å to about 1,000 Å, for example, about 20 Å to about 700 Å, about 20 Å to about 500 Å, about 20 Å to about 400 Å, about 30 Å to about 400 Å or about 30 Å to about 300 Å. When the thicknesses of the buffer layer, the hole blocking layer, and the electron control layer are within these ranges, excellent hole blocking characteristics or excellent electron control characteristics may be obtained without a substantial increase in driving voltage.

[0176] A thickness of the electron transport layer may be in a range of about 100 Å to about 1,000 Å, for example, about 100 Å to about 700 Å, about 100 Å to about 600 Å, about 150 Å to about 600 Å, about 150 Å to about 500 Å or about 200 Å to about 400 Å. When the thickness of the electron transport layer is within the range described above, the electron transport layer may have suitable or satisfactory electron transport characteristics without a substantial increase in driving voltage.

[0177] 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.

[0178] The metal-containing material may include at least one selected from alkali metal complex and alkaline earth-metal complex. The alkali metal complex may include a metal ion selected from a Li ion, a Na ion, a K ion, a Rb ion, and a Cs ion, and the alkaline earth-metal complex may include a metal ion selected from a Be ion, a Mg ion, a Ca ion, a Sr ion, and a Ba ion. A ligand coordinated with the metal ion of the alkali metal complex or the alkaline earth-metal complex may be selected from a hydroxy quinoline, a hydroxy isoquinoline, a hydroxy benzoquinoline, a hydroxy acridine, a hydroxy phenanthridine, a hydroxy phenyloxazole, a hydroxy phenylthiazole, a hydroxy diphenyloxadiazole, a hydroxy 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.

[0179] 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:



[0180] The electron transport region may include an electron injection layer that facilitates electron injection from the second electrode 190. The electron injection layer may directly contact (e.g., physically contact) the second electrode 190.

[0181] 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.

[0182] 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.

[0183] In one embodiment, the electron injection layer may include Li, Na, K, Rb, Cs, Mg, Ca, Er, Tm, Yb, or any combination thereof, but embodiments of the present disclosure are not limited thereto.

[0184] 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.

[0185] The alkaline earth metal may be selected from Mg, Ca, Sr, and Ba.

[0186] The rare earth metal may be selected from Sc, Y, Ce, Tm, Yb, Gd, and Tb.

[0187] 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.

[0188] The alkali metal compound may be selected from alkali metal oxides, such as Li_2O , Cs_2O , or K_2O , and alkali metal halides, such as LiF , NaF , CsF , KF , LiI , NaI , CsI , or KI . In one embodiment, the alkali metal compound may be selected from LiF , Li_2O , NaF , LiI , NaI , CsI , and KI , but embodiments of the present disclosure are not limited thereto.

[0189] The alkaline earth-metal compound may be selected from alkaline earth-metal oxides, such as BaO , SrO , CaO , $\text{Ba}_x\text{Sr}_{1-x}\text{O}$ ($0 < x < 1$), 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.

[0190] The rare earth metal compound may be selected from YbF_3 , ScF_3 , SCO_3 , Sc_2O_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.

[0191] 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 phenyloxadiazole, hydroxy phenylthiadiazole, hydroxy phenylpyridine, hydroxy phenylbenzimidazole, hydroxy phenylbenzothiazole, bipyridine, phenanthroline, and cyclopentadiene, but embodiments of the present disclosure are not limited thereto.

[0192] The electron injection layer may include (or 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 combination thereof may be homogeneously or non-homogeneously dispersed in a matrix including the organic material.

[0193] 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 or about 3 Å to about 20 Å. When the thickness of the electron injection layer is within the range described above, the electron injection layer may have suitable or satisfactory electron injection characteristics without a substantial increase in driving voltage.

[0194] In one embodiment, the electron transport region in the organic light-emitting device 10 may include a buffer layer, an electron transport layer, and an electron injection layer, and

at least one layer selected from the electron transport layer and 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 combination thereof.

Second electrode 190

[0195] The second electrode 190 is located on the organic layer 150 having such a structure. The second electrode 190 may be a cathode, which is an electron injection electrode, and as a material for forming the second electrode 190, a metal, an alloy, an electrically conductive compound, and any combination thereof, each having a low work function,

may be used.

[0196] The second electrode 190 may include at least one selected from lithium (Li), silver (Ag), magnesium (Mg), aluminium (Al), aluminium-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 trans-

missive electrode, a semi-transmissive electrode, or a reflective electrode.

[0197] 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

[0198] 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. 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.

[0199] 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.

[0200] 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.

[0201] The first capping layer 210 and the second capping layer 220 may increase external luminescent efficiency according to the principle of constructive interference.

[0202] 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.

[0203] 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 carbocyclic compounds, heterocyclic compounds, amine-based compounds, porphyrin derivatives, phthalocyanine derivatives, a naphthalocyanine derivatives, alkali metal complexes, and alkaline earth-metal 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 of the first capping layer 210 and the second capping layer 220 may each independently include an amine-based compound.

[0204] 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.

[0205] Hereinbefore, the organic light-emitting device according to an embodiment has been described in connection with FIGS. 1 to 4. However, embodiments of the present disclosure are not limited thereto.

[0206] Layers constituting the hole transport region, an emission layer, and layers constituting the electron transport region may be formed in a set or certain region by using one or more suitable methods selected from vacuum deposition, spin coating, casting, Langmuir-Blodgett (LB) deposition, ink-jet printing, laser-printing, and laser-induced thermal imaging.

[0207] When layers constituting the hole transport region, an emission layer, and layers constituting the electron transport region are formed by vacuum deposition, the deposition may be performed at a deposition temperature of about 100 °C to about 500 °C, a vacuum degree of about 10⁻⁸ torr to about 10⁻³ torr, and a deposition speed of about 0.01 Å/sec to about 100 Å/sec by taking into consideration a compound to be included in a layer to be formed and the structure of a layer to be formed.

[0208] When layers constituting the hole transport region, an emission layer, and layers constituting the electron transport region are formed by spin coating, the spin coating may be performed at a coating speed of about 2,000 rpm to about 5,000 rpm and at a heat treatment temperature of about 80 °C to 200 °C by taking into consideration a compound to be included in a layer to be formed and the structure of a layer to be formed.

General definition of at least some of the substituents

[0209] 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 isoamyl group, and a hexyl group. The

term "C₁-C₆₀ alkylene group," as used herein, refers to a divalent group having substantially the same structure as the C₁-C₆₀ alkyl group. Corresponding definitions apply to other ranges given for the number of carbon atoms in an alkyl/alkylene group.

[0210] The term "C₂-C₆₀ alkenyl group," as used herein, refers to a hydrocarbon group having at least one carbon-carbon double bond at a main chain (e.g., in the middle) or at a terminal end (e.g., 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 substantially the same structure as the C₂-C₆₀ alkenyl group. Corresponding definitions apply to other ranges given for the number of carbon atoms in an alkenyl/alkenylene group.

[0211] The term "C₂-C₆₀ alkynyl group," as used herein, refers to a hydrocarbon group having at least one carbon-carbon triple bond at a main chain (e.g., in the middle) or at a terminal end (e.g., 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 substantially the same structure as the C₂-C₆₀ alkynyl group. Corresponding definitions apply to other ranges given for the number of carbon atoms in an alkynyl/alkynylene group.

[0212] 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. Corresponding definitions apply to other ranges given for the number of carbon atoms in an alkoxy group.

[0213] 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 substantially the same structure as the C₃-C₁₀ cycloalkyl group.

[0214] 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 tetrahydrofuranyl group, and a tetrahydrothiophenyl group. The term "C₁-C₁₀ heterocycloalkylene group," as used herein, refers to a divalent group having substantially the same structure as the C₁-C₁₀ heterocycloalkyl group.

[0215] The term "C₃-C₁₀ cycloalkenyl group," as used herein refers to a monovalent monocyclic group that has 3 to 10 carbon atoms and at least one carbon-carbon double bond in the ring thereof and no aromaticity (e.g., is not aromatic), 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 substantially the same structure as the C₃-C₁₀ cycloalkenyl group.

[0216] 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 carbon-carbon double bond in its ring. Examples of the C₁-C₁₀ heterocycloalkenyl group include a 4,5-dihydro-1,2,3,4-oxatriazolyl group, a 2,3-hydrofuranyl group, and a 2,3-hydrothiophenyl group. The term "C₁-C₁₀ heterocycloalkenylene group," as used herein, refers to a divalent group having substantially the same structure as the C₁-C₁₀ heterocycloalkenyl group.

[0217] 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. Examples of the C₆-C₆₀ aryl group include a fluorenyl group, 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 two or more rings may be fused to each other (e.g., combined together). The C₇-C₆₀ alkylaryl group used herein refers to a C₆-C₆₀ aryl group substituted with at least one C₁-C₆₀ alkyl group. Corresponding definitions apply to other ranges given for the number of carbon atoms in an aryl/arylene group.

[0218] The term "C₁-C₆₀ heteroaryl group," as used herein, refers to a monovalent group having a carbocyclic 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 carbocyclic 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. Examples of the C₁-C₆₀ heteroaryl group include a carbazolyl group, 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 two or more rings may be condensed with each other (e.g., combined together). The C₇-C₆₀ alkylaryl group used herein refers to a C₆-C₆₀ aryl group substituted with at least one C₁-C₆₀ alkyl group. Corresponding definitions apply to other ranges given for the number of carbon atoms in an heteroaryl/heteroarylene group.

[0219] The term "C₆-C₆₀ aryloxy group," as used herein, refers to -OA₁₀₂ (wherein A₁₀₂ is the C₆-C₆₀ aryl group), and the term "C₆-C₆₀ arylthio group," as used herein, refers to -SA₁₀₃ (wherein A₁₀₃ is the C₆-C₆₀ aryl group). Corresponding definitions apply to other ranges given for the number of carbon atoms in an aryloxy group and an arylthio group.

[0220] 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 (e.g., combined together), only carbon atoms as ring-forming atoms, and no aromaticity in its entire molecular structure. An 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 substantially the same structure as the monovalent non-aromatic condensed polycyclic group.

[0221] The term "monovalent non-aromatic condensed heteropolycyclic group," as used herein, refers to a monovalent group (for example, having 1 to 60 carbon atoms) having two or more rings condensed to each other (e.g., combined together), at least one heteroatom selected from N, O, Si, P, and S, other than carbon atoms, as a ring-forming atom, and no aromaticity in its entire molecular structure (e.g., is not aromatic). 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 substantially the same structure as the monovalent non-aromatic condensed heteropolycyclic group.

[0222] The term " C_5 - C_{60} carbocyclic group," as used herein, refers to a monocyclic or polycyclic group that includes only carbon as a ring-forming atom and includes (or consists of) 5 to 60 carbon atoms. The C_5 - C_{60} carbocyclic group may be an aromatic carbocyclic group or a non-aromatic carbocyclic group. The C_5 - C_{60} carbocyclic group may be a ring, such as benzene, a monovalent group, such as a phenyl group, or a divalent group, such as a phenylene group. In one or more embodiments, depending on the number of substituents connected to the C_5 - C_{60} carbocyclic group, the C_5 - C_{60} carbocyclic group may be a trivalent group or a quadrivalent group. Corresponding definitions apply to other ranges given for the number of carbon atoms in a carbocyclic group.

[0223] The term " C_1 - C_{60} heterocyclic group," as used herein, refers to a group having substantially the same structure as the C_5 - C_{60} carbocyclic group, except that as a ring-forming atom, at least one heteroatom selected from N, O, Si, P, and S is used in addition to carbon (the number of carbon atoms may be in a range of 1 to 60). Corresponding definitions apply to other ranges given for the number of carbon atoms in a heterocyclic group.

[0224] In the present specification, at least one substituent of the substituted C_5 - C_{60} (e.g. C_5 - C_{30}) carbocyclic group, the substituted C_1 - C_{60} (e.g. C_1 - C_{20}) heterocyclic group, the substituted C_3 - C_{10} cycloalkylene group, the substituted C_1 - C_{10} heterocycloalkylene group, the substituted C_3 - C_{10} cycloalkenylene group, the substituted C_1 - C_{10} heterocycloalkenylene group, the substituted C_6 - C_{60} (e.g. C_6 - C_{30}) arylene group, the substituted C_1 - C_{60} (e.g. C_1 - C_{20}) heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, the substituted divalent non-aromatic condensed heteropolycyclic group, the substituted C_1 - C_{60} (e.g. C_1 - C_{20}) alkyl group, the substituted C_2 - C_{60} (e.g. C_2 - C_{20}) alkenyl group, the substituted C_2 - C_{60} (e.g. C_2 - C_{20}) alkynyl group, the substituted C_1 - C_{60} (e.g. C_1 - C_{20}) alkoxy group, the substituted C_3 - C_{10} cycloalkyl group, the substituted C_1 - C_{10} heterocycloalkyl group, the substituted C_3 - C_{10} cycloalkenyl group, the substituted C_1 - C_{10} heterocycloalkenyl group, the substituted C_6 - C_{60} (e.g. C_6 - C_{30}) aryl group, the substituted C_7 - C_{60} (e.g. C_7 - C_{30}) alkylaryl group, the substituted C_6 - C_{60} (e.g. C_6 - C_{30}) aryloxy group, the substituted C_6 - C_{60} (e.g. C_6 - C_{30}) arylthio group, the substituted C_1 - C_{60} (e.g. C_1 - C_{20}) heteroaryl group, the substituted C_2 - C_{60} (e.g. C_2 - C_{20}) alkylheteroaryl group, the substituted C_1 - C_{60} (e.g. C_1 - C_{20}) heteroaryloxy group, the substituted C_1 - C_{60} (e.g. C_1 - C_{20}) heteroarylthio group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group 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 C_1 - C_{60} (e.g. C_1 - C_{20}) alkyl group, a C_2 - C_{60} (e.g. C_2 - C_{20}) alkenyl group, a C_2 - C_{60} (e.g. C_2 - C_{20}) alkynyl group, and a C_1 - C_{60} (e.g. C_1 - C_{20}) alkoxy group;

a C_1 - C_{60} (e.g. C_1 - C_{20}) alkyl group, a C_2 - C_{60} (e.g. C_2 - C_{20}) alkenyl group, a C_2 - C_{60} (e.g. C_2 - C_{20}) alkynyl group, and a C_1 - C_{60} (e.g. C_1 - C_{20}) alkoxy group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} (e.g. C_6 - C_{30}) aryl group, a C_7 - C_{60} (e.g. C_7 - C_{30}) alkylaryl group, a C_6 - C_{60} (e.g. C_6 - C_{30}) aryloxy group, a C_6 - C_{60} (e.g. C_6 - C_{30}) arylthio group, a C_1 - C_{60} (e.g. C_1 - C_{20}) heteroaryl group, a C_2 - C_{60} (e.g. C_2 - C_{20}) alkylheteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, -O(Q_{11}), -S(Q_{11}), -Si(Q_{11})(Q_{12})(Q_{13}), -N(Q_{11})(Q_{12}), -B(Q_{11})(Q_{12}), -P(Q_{11})(Q_{12}), -C(=O)(Q_{11}), -S(=O)₂(Q_{11}), and -P(=O)(Q_{11})(Q_{12});

a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} (e.g. C_6 - C_{30}) aryl group, a C_7 - C_{60} (e.g. C_7 - C_{30}) alkylaryl group, a C_6 - C_{60} (e.g. C_6 - C_{30}) aryloxy group, a C_6 - C_{60} (e.g. C_6 - C_{30}) arylthio group, a C_1 - C_{60} (e.g. C_1 - C_{20}) heteroaryl group, a C_2 - C_{60} (e.g. C_2 - C_{20}) alkylheteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} (e.g. C_6 - C_{30}) aryl group, a C_7 - C_{60} (e.g. C_7 - C_{30}) alkylaryl group, a C_6 - C_{60} (e.g. C_6 - C_{30}) aryloxy

group, a C₆-C₆₀ (e.g. C₆-C₃₀) arylthio group, a C₁-C₆₀ (e.g. C₁-C₂₀) heteroaryl group, a C₂-C₆₀ (e.g. C₂-C₂₀) alkyl-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 (e.g. C₁-C₂₀) alkyl group, a C₂-C₆₀ (e.g. C₂-C₂₀) alkenyl group, a C₂-C₆₀ (e.g. C₂-C₂₀) alkynyl group, a C₁-C₆₀ (e.g. C₁-C₂₀) 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 (e.g. C₆-C₃₀) aryl group, a C₇-C₆₀ (e.g. C₇-C₃₀) alkylaryl group, a C₆-C₆₀ (e.g. C₆-C₃₀) aryloxy group, a C₆-C₆₀ (e.g. C₆-C₃₀) arylthio group, a C₁-C₆₀ (e.g. C₁-C₂₀) heteroaryl group, a C₂-C₆₀ (e.g. C₂-C₂₀) alkylheteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, -O(Q₂₁), -S(Q₂₁), -Si(Q₂₁)(Q₂₂)(Q₂₃), -N(Q₂₁)(Q₂₂), -B(Q₂₁)(Q₂₂), -P(Q₂₁)(Q₂₂), -C(=O)(Q₂₁), -S(=O)₂(Q₂₁), and -P(=O)(Q₂₁)(Q₂₂); and -O(Q₃₁), -S(Q₃₁), -Si(Q₃₁)(Q₃₂)(Q₃₃), -N(Q₃₁)(Q₃₂), -B(Q₃₁)(Q₃₂), -P(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 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 (e.g. C₁-C₂₀) alkyl group, a C₂-C₆₀ (e.g. C₂-C₂₀) alkenyl group, a C₂-C₆₀ (e.g. C₂-C₂₀) alkynyl group, a C₁-C₆₀ (e.g. C₁-C₂₀) 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 (e.g. C₆-C₃₀) aryl group, a C₆-C₆₀ (e.g. C₆-C₃₀) aryloxy group, a C₆-C₆₀ (e.g. C₆-C₃₀) arylthio group, a C₁-C₆₀ (e.g. C₁-C₂₀) heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a C₁-C₆₀ (e.g. C₁-C₂₀) alkyl group that is substituted with at least one selected from deuterium, -F, a cyano group, a C₁-C₆₀ (e.g. C₁-C₂₀) alkyl group, a phenyl group, a terphenyl group, and a biphenyl group, and a C₆-C₆₀ (e.g. C₆-C₃₀) aryl group that is substituted with at least one selected from deuterium, -F, a cyano group, a C₁-C₁₀ alkyl group, a phenyl group, and a biphenyl group.

[0225] The term "Ph," as used herein, refers to a phenyl group, the term "Me," as used herein, refers to a methyl group, the term "Et," as used herein, refers to an ethyl group, the term "tert-Bu" or "Bu^t," as used herein, refers to a tert-butyl group, and the term "OMe," as used herein, refers to a methoxy group.

[0226] The term "biphenyl group," as used herein, refers to "a phenyl group substituted with a phenyl group." In some embodiments, the "biphenyl group" is a substituted phenyl group having a C₆-C₆₀ aryl group as a substituent.

[0227] The term "terphenyl group," as used herein, refers to "a phenyl group substituted with a biphenyl group." In some embodiments, the "terphenyl group" is a substituted phenyl group having, as a substituent, a C₆-C₆₀ aryl group substituted with a C₆-C₆₀ aryl group.

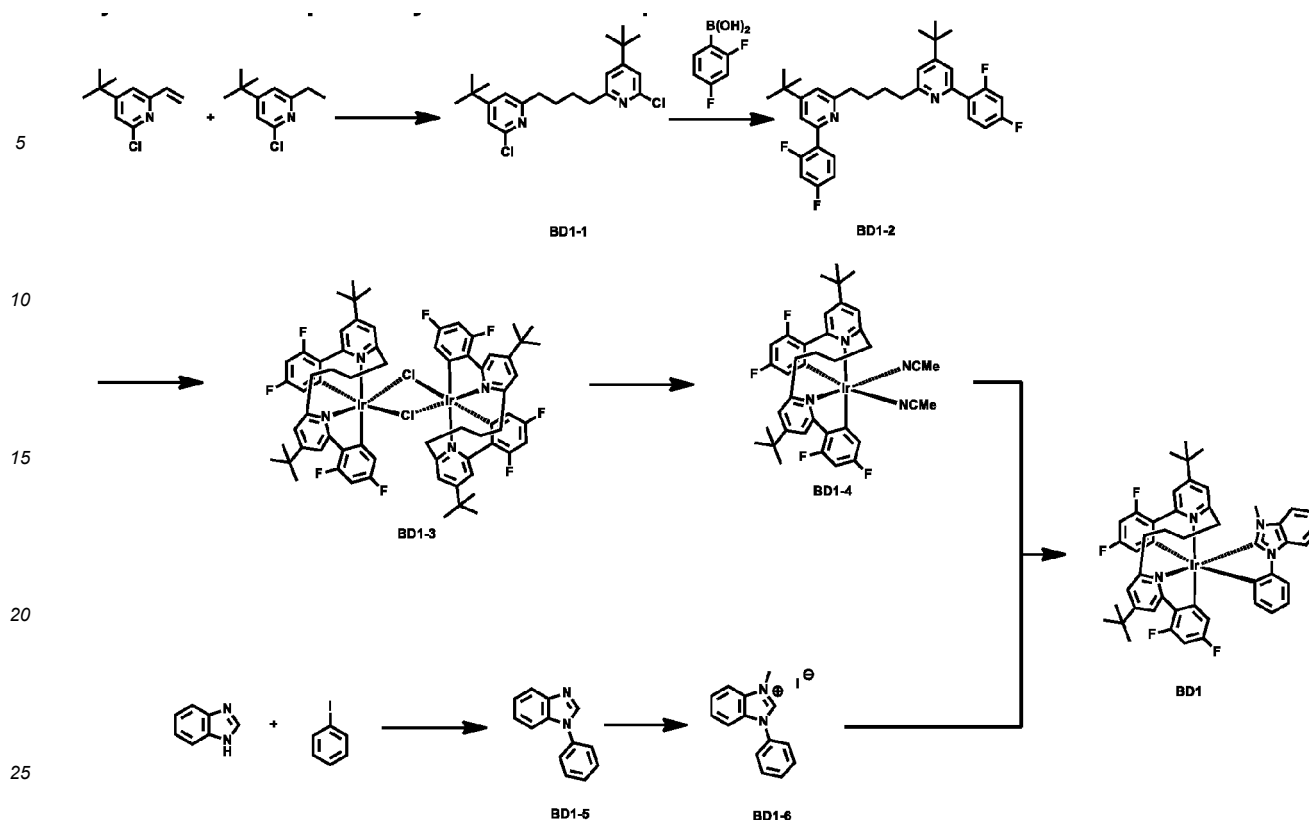
[0228] * and *' as used herein, unless defined otherwise, each refer to a binding site to a neighboring atom in a corresponding formula.

[0229] 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 wording "B was used instead of A" used in describing Synthesis Examples refers to that an identical molar equivalent of B was used in place of A.

Examples

Synthesis Example 1: Synthesis of Compound BD1

[0230]



Synthesis of Intermediate Compound [BD1-1]

[0231] 4-(tert-butyl)-2-chloro-6-ethylpyridine (1.0 eq) and sodium (0.03 eq) were stirred for 1 hour, and 4-(tert-butyl)-2-chloro-6-vinylpyridine (1.0 eq) was added to the mixed solution and stirred again at a temperature of 120 °C for 4 hours. After the reaction mixture was cooled to 0 °C, methanol was added thereto to terminate the reaction. Then, an extraction process was performed thereon three times using dichloromethane and water, so as to obtain an organic layer. The obtained organic layer was dried by using anhydrous MgSO_4 , concentrated, and subjected to column chromatography, so as to synthesize Intermediate Compound [BD1-1] (yield: 40 %).

Synthesis of Intermediate Compound [BD1-2]

[0232] Intermediate Compound [BD1-1] (1.0 eq), 2,4-difluorophenylboronic acid (3.0 eq), K_2CO_3 (2.0 eq), and $\text{Pd}(\text{PPh}_3)_4$ (0.02 eq) were dissolved in toluene (0.1M), and the mixed solution was stirred at a temperature of 120 °C for 12 hours. After the reaction mixture was cooled to room temperature, an extraction process was performed thereon three times using dichloromethane and water, so as to obtain an organic layer. The obtained organic layer was dried by using anhydrous MgSO_4 , concentrated, and subjected to column chromatography, so as to synthesize Intermediate Compound [BD1-2] (yield: 80 %).

Synthesis of Intermediate Compound [BD1-3]

[0233] Intermediate Compound [BD1-2] (1.0 eq), $[\text{Ir}(\text{COD})\text{OMe}]_2$ (1.1 eq), Ag_2O (0.5 eq), and sodium tert-butoxide (3.0 eq) were dissolved in 2-ethoxyethanol (0.5 M), and the mixed solution was stirred at a temperature of 120 °C for 10 hours. After the reaction mixture was cooled to room temperature, an extraction process was performed thereon three times using dichloromethane and water, so as to obtain an organic layer. The obtained organic layer was dried by using anhydrous MgSO_4 , concentrated, and subjected to column chromatography, so as to synthesize Intermediate Compound [BD1-3] (yield: 21 %).

Synthesis of Intermediate Compound [BD1-4]

[0234] Intermediate Compound [BD1-3] (1.0 eq) and silver triflate (1.2 eq) were dissolved in acetone (1.0 M), and the mixed solution was stirred at room temperature for 4 hours. After the reaction mixture was subjected to decompression

(reduced pressure) to remove the solvent therefrom, acetonitrile (20 eq) was added thereto and stirred again for 0.5 hours. The solvent was removed therefrom under reduced pressure, and the resulting product was concentrated, so as to synthesize Intermediate Compound [BD1-4] (yield: 81 %).

Synthesis of Intermediate Compound [BD1-5]

[0235] Iodobenzene (1.0 eq), benzimidazole (1.2 eq), CuI (0.01 eq), K₂CO₃ (2.0 eq), and L-proline (0.02 eq) were dissolved in dimethylsulfoxide (0.1 M), and the mixed solution was stirred at a temperature of 160 °C for 48 hours. After the reaction mixture was cooled to room temperature, an extraction process was performed thereon three times using dichloromethane and water, so as to obtain an organic layer. The obtained organic layer was dried by using anhydrous MgSO₄, concentrated, and subjected to column chromatography, so as to synthesize Intermediate Compound [BD1-5] (yield: 65 %).

Synthesis of Intermediate Compound [BD1-6]

[0236] Intermediate Compound [BD1-5] (1.0 eq) and iodomethane (3.0 eq) were dissolved in THF (1.0 M), and the mixed solution was stirred at a temperature of 70 °C for 12 hours. After the reaction mixture was cooled to room temperature, an extraction process was performed thereon three times using dichloromethane and water, so as to obtain an organic layer. The obtained organic layer was dried by using anhydrous MgSO₄, concentrated, and subjected to column chromatography, so as to synthesize Intermediate Compound [BD1-6] (yield: 66 %).

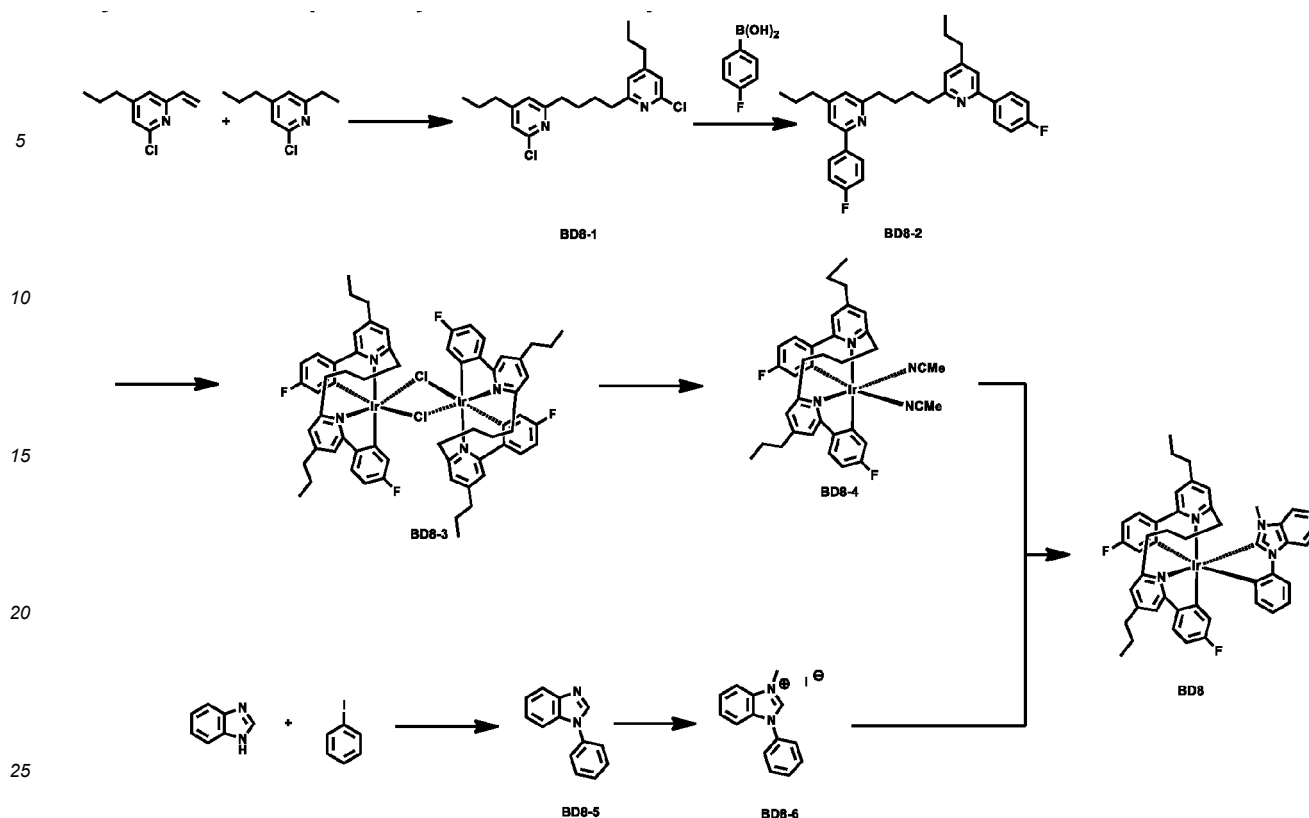
Synthesis of Compound BD1

[0237] Intermediate Compound [BD1-4], Intermediate Compound [BD1-6], and K₂CO₃ (10.0 eq) were dissolved in 2-ethoxyethanol (0.05 M), and the mixed solution was stirred at a temperature of 120 °C for 10 hours. After the reaction mixture was cooled to room temperature, an extraction process was performed thereon three times using dichloromethane and water, so as to obtain an organic layer. The obtained organic layer was dried by using anhydrous MgSO₄, concentrated, and subjected to column chromatography, so as to synthesize Compound [BD1] (yield: 61 %).

¹H NMR (400 MHz, CDCl₃): δ= 7.67 (d, 2H), 7.43(d, 2H), 7.30 (m, 4H), 7.08 (d, 1H), 7.00 (m, 4H), 6.77 (d, 2H), 6.71 (t, 1H), 3.36 (s, 3H), 2.98 (t, 4H), 1.95 (m, 2H), 1.32 (s, 18H)
LC-MS. Calculated for C₄₇H₄₃F₄IrN₄([M]⁺):m/z 932.10 Found: m/z 932.31

Synthesis Example 2: Synthesis of Compound BD8

[0238]



Synthesis of Intermediate Compound [BD8-1]

[0239] 2-chloro-6-ethyl-4-propylpyridine (1.0 eq) and sodium (0.03 eq) were stirred for 1 hour, and 2-chloro-4-propyl-6-vinylpyridine (1.0 eq) was added thereto and stirred again at a temperature of 120 °C for 4 hours. After the reaction mixture was cooled to 0 °C, methanol was added thereto to terminate the reaction. Then, an extraction process was performed thereon three times using dichloromethane and water, so as to obtain an organic layer. The obtained organic layer was dried by using anhydrous MgSO_4 , concentrated, and subjected to column chromatography, so as to synthesize Intermediate Compound [BD8-1] (yield: 40 %).

Synthesis of Intermediate Compound [BD8-2]

[0240] Intermediate Compound [BD8-1] (1.0 eq), 4-fluorophenylboronic acid (3.0 eq), K_2CO_3 (2.0 eq), and $\text{Pd}(\text{PPh}_3)_4$ (0.02 eq) were dissolved in toluene (0.1 M), and the mixed solution was stirred at a temperature of 120 °C for 12 hours. After the reaction mixture was cooled to room temperature, an extraction process was performed thereon three times using dichloromethane and water, so as to obtain an organic layer. The obtained organic layer was dried by using anhydrous MgSO_4 , concentrated, and subjected to column chromatography, so as to synthesize Intermediate Compound [BD8-2] (yield: 80 %).

Synthesis of Intermediate Compound [BD8-3]

[0241] Intermediate Compound [BD8-2] (1.0 eq), $[\text{Ir}(\text{COD})\text{OMe}]_2$ (1.1 eq), Ag_2O (0.5 eq), and sodium tert-butoxide (3.0 eq) were dissolved in 2-ethoxyethanol (0.5 M), and the mixed solution was stirred at a temperature of 120 °C for 10 hours. After the reaction mixture was cooled to room temperature, an extraction process was performed thereon three times using dichloromethane and water, so as to obtain an organic layer. The obtained organic layer was dried by using anhydrous MgSO_4 , concentrated, and subjected to column chromatography, so as to synthesize Intermediate Compound [BD8-3] (yield: 21 %).

Synthesis of Intermediate Compound [BD8-4]

[0242] Intermediate Compound [BD8-3] (1.0 eq) and silver triflate (1.2 eq) were dissolved in acetone (1.0 M), and the mixed solution was stirred at room temperature for 4 hours. After the reaction mixture was subjected to decompression

(reduced pressure) to remove the solvent therefrom, acetonitrile (20 eq) was added thereto and stirred again for 0.5 hours. The solvent was removed therefrom under reduced pressure, and the resulting product was concentrated, so as to synthesize Intermediate Compound [BD8-4] (yield: 81 %).

Synthesis of Intermediate Compound [BD8-5]

[0243] Iodobenzene (1.0 eq), benzimidazole (1.2 eq), CuI (0.01 eq), K₂CO₃ (2.0 eq), and L-proline (0.02 eq) were dissolved in dimethylsulfoxide (0.1 M), and the mixed solution was stirred at a temperature of 160 °C for 48 hours. After the reaction mixture was cooled to room temperature, an extraction process was performed thereon three times using dichloromethane and water, so as to obtain an organic layer. The obtained organic layer was dried by using anhydrous MgSO₄, concentrated, and subjected to column chromatography, so as to synthesize Intermediate Compound [BD8-5] (yield: 65 %).

Synthesis of Intermediate Compound [BD8-6]

[0244] Intermediate Compound [BD8-5] (1.0 eq) and iodomethane (3.0 eq) were dissolved in THF (1.0 M), and the mixed solution was stirred at a temperature of 70 °C for 12 hours. After the reaction mixture was cooled to room temperature, an extraction process was performed thereon three times using dichloromethane and water, so as to obtain an organic layer. The obtained organic layer was dried by using anhydrous MgSO₄, concentrated, and subjected to column chromatography, so as to synthesize Intermediate Compound [BD8-6] (yield: 66 %).

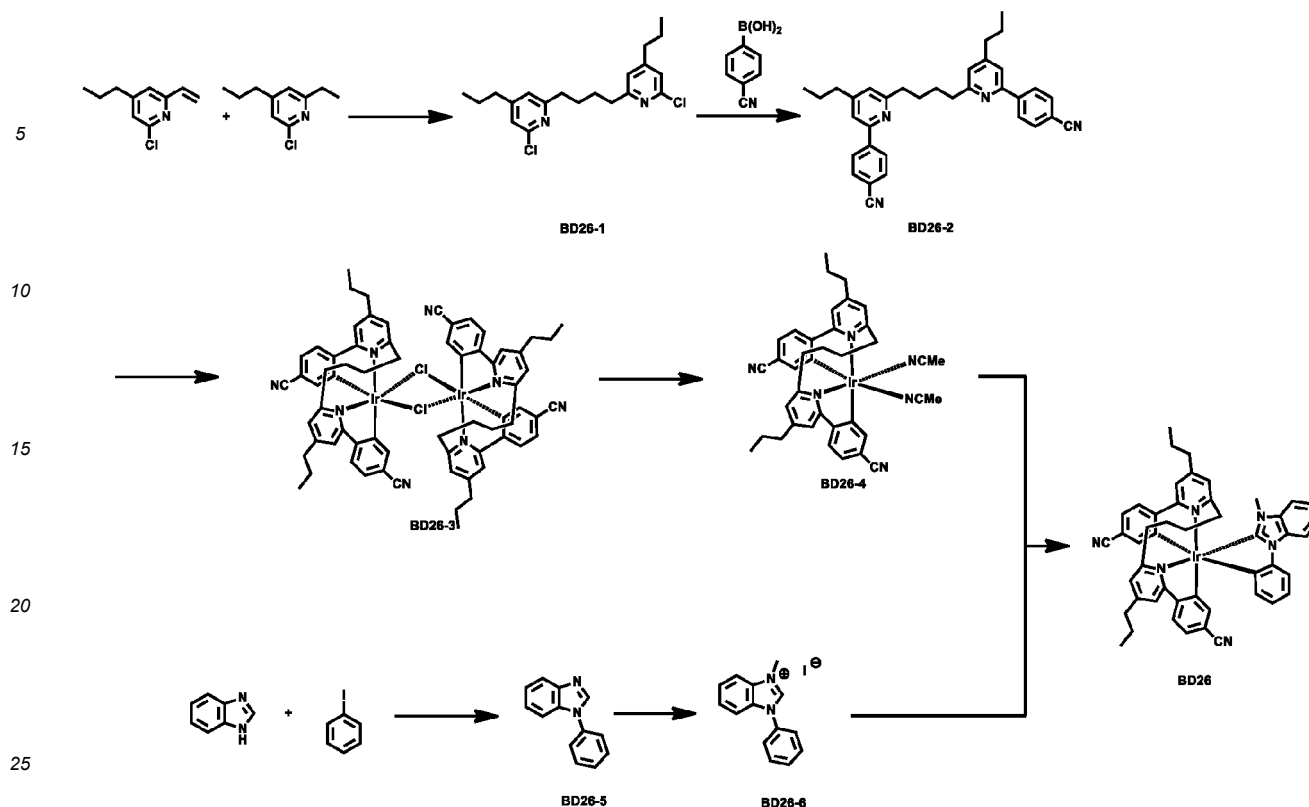
Synthesis of Compound BD8

[0245] Intermediate Compound [BD8-4], Intermediate Compound [BD8-6], and K₂CO₃ (10.0 eq) were dissolved in 2-ethoxyethanol (0.05 M), and the mixed solution was stirred at a temperature of 120 °C for 10 hours. After the reaction mixture was cooled to room temperature, an extraction process was performed thereon three times using dichloromethane and water, so as to obtain an organic layer. The obtained organic layer was dried by using anhydrous MgSO₄, concentrated, and subjected to column chromatography, so as to synthesize Compound [BD8] (yield: 61 %).

¹H NMR (400 MHz, CDCl₃): δ= 7.87 (d, 2H), 7.51 (d, 2H), 7.29 (m, 4H), 7.18 (d, 1H), 7.10 (m, 4H), 7.02 (d, 2H), 6.85 (d, 2H), 6.77 (t, 1H), 3.43 (t, 4H), 3.36 (s, 3H), 2.98 (t, 4H), 1.95 (m, 2H), 1.65 (m, 4H), 1.65 (t, 6H)
LC-MS. Calculated for C₄₅H₄₁F₂IrN₄ ([M]⁺): m/z 868.06. Found: m/z 868.29

Synthesis Example 3: Synthesis of Compound BD26

[0246]



Synthesis of Intermediate Compound [BD26-1]

[0247] 2-chloro-6-ethyl-4-propylpyridine (1.0 eq) and sodium (0.03 eq) were stirred for 1 hour, and 2-chloro-4-propyl-6-vinylpyridine (1.0 eq) was added thereto and stirred again at a temperature of 120 °C for 4 hours. After the reaction mixture was cooled to 0 °C, methanol was added thereto to terminate the reaction. Then, an extraction process was performed thereon three times using dichloromethane and water, so as to obtain an organic layer. The obtained organic layer was dried by using anhydrous MgSO_4 , concentrated, and subjected to column chromatography, so as to synthesize Intermediate Compound [BD26-1] (yield: 40 %).

Synthesis of Intermediate Compound [BD26-2]

[0248] Intermediate Compound [BD26-1] (1.0 eq), 4-cyanophenylboronic acid (3.0 eq), K_2CO_3 (2.0 eq), and $\text{Pd}(\text{PPh}_3)_4$ (0.02 eq) were dissolved in toluene (0.1M), and the mixed solution was stirred at a temperature of 120 °C for 12 hours. After the reaction mixture was cooled to room temperature, an extraction process was performed thereon three times using dichloromethane and water, so as to obtain an organic layer. The obtained organic layer was dried by using anhydrous MgSO_4 , concentrated, and subjected to column chromatography, so as to synthesize Intermediate Compound [BD26-2] (yield: 80 %).

Synthesis of Intermediate Compound [BD26-3]

[0249] Intermediate Compound [BD26-2] (1.0 eq), $[\text{Ir}(\text{COD})\text{OMe}]_2$ (1.1 eq), Ag_2O (0.5 eq), and sodium tert-butoxide (3.0 eq) were dissolved in 2-ethoxyethanol (0.5 M), and the mixed solution was stirred at a temperature of 120 °C for 10 hours. After the reaction mixture was cooled to room temperature, an extraction process was performed thereon three times using dichloromethane and water, so as to obtain an organic layer. The obtained organic layer was dried by using anhydrous MgSO_4 , concentrated, and subjected to column chromatography, so as to synthesize Intermediate Compound [BD26-3] (yield: 21 %).

Synthesis of Intermediate Compound [BD26-4]

[0250] Intermediate Compound [BD26-3] (1.0 eq) and silver triflate (1.2 eq) were dissolved in acetone (1.0 M), and the mixed solution was stirred at room temperature for 4 hours. After the reaction mixture was subjected to decompression

to remove the solvent therefrom, acetonitrile (20 eq) was added thereto and stirred again for 0.5 hours. The solvent was removed therefrom under reduced pressure, and the resulting product was concentrated, so as to synthesize Intermediate Compound [BD26-4] (yield: 81 %).

Synthesis of Intermediate Compound [BD26-5]

[0251] Iodobenzene (1.0 eq), benzimidazole (1.2 eq), CuI (0.01 eq), K₂CO₃ (2.0 eq), and L-proline (0.02 eq) were dissolved in dimethylsulfoxide (0.1 M), and the mixed solution was stirred at a temperature of 160 °C for 48 hours. After the reaction mixture was cooled to room temperature, an extraction process was performed thereon three times using dichloromethane and water, so as to obtain an organic layer. The obtained organic layer was dried by using anhydrous MgSO₄, concentrated, and subjected to column chromatography, so as to synthesize Intermediate Compound [BD26-5] (yield: 65 %).

Synthesis of Intermediate Compound [BD26-6]

[0252] Intermediate Compound [BD25-5] (1.0 eq) and iodomethane (3.0 eq) were dissolved in THF (1.0 M), and the mixed solution was stirred at a temperature of 70 °C for 12 hours. After the reaction mixture was cooled to room temperature, an extraction process was performed thereon three times using dichloromethane and water, so as to obtain an organic layer. The obtained organic layer was dried by using anhydrous MgSO₄, concentrated, and subjected to column chromatography, so as to synthesize Intermediate Compound [BD26-6] (yield: 66 %).

Synthesis of Compound BD26

[0253] Intermediate Compound [BD26-4], Intermediate Compound [BD26-6], and K₂CO₃ (10.0 eq) were dissolved in 2-ethoxyethanol (0.05 M), and the mixed solution was stirred at a temperature of 120 °C for 10 hours. After the reaction mixture was cooled to room temperature, an extraction process was performed thereon three times using dichloromethane and water, so as to obtain an organic layer. The obtained organic layer was dried by using anhydrous MgSO₄, concentrated, and subjected to column chromatography, so as to synthesize Compound [BD26] (yield: 61 %).

¹H NMR (400 MHz, CDCl₃): δ= 7.97 (d, 2H), 7.61 (d, 2H), 7.39 (m, 4H), 7.21 (d, 1H), 7.15 (m, 4H), 7.08 (d, 2H), 6.89 (d, 2H), 6.67 (t, 1H), 3.43 (t, 4H), 3.36 (s, 3H), 2.98 (t, 4H), 1.95 (m, 2H), 1.65 (m, 4H), 1.65 (t, 6H)
LC-MS. Calculated for C₄₇H₄₁IrN₆([M]⁺): m/z 882.10 Found: m/z 882.30

Evaluation Example 1

[0254] According to evaluation methods described in Table 1, the HOMO energy level and the LUMO energy level of each of Compounds BD1, BD8, BD26, ETH7, HTH26, and A were evaluated, and the results are shown in Table 2.

Table 1

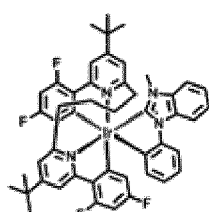
| | |
|-------------------------------------|---|
| HOMO energy level evaluation method | Cyclic voltammetry (CV) (electrolyte: 0.1 M Bu ₄ NPF ₆ / solvent: dimethylformamide (DMF) / electrode: 3-electrode system (working electrode: GC, reference electrode: Ag/AgCl, auxiliary electrode: Pt)) was used to obtain a voltage (V)-current (A) graph for each compound. Then, a HOMO energy level of each compound was calculated from an oxidation onset of the graph. |
| LUMO energy level evaluation method | Cyclic voltammetry (CV) (electrolyte: 0.1 M Bu ₄ NPF ₆ / solvent: dimethylformamide (DMF) / electrode: 3-electrode system (working electrode: GC, reference electrode: Ag/AgCl, auxiliary electrode: Pt)) was used to obtain a voltage (V)-current (A) graph for each compound. Then, a LUMO energy level of each compound was calculated from a reduction onset of the graph. |

Table 2

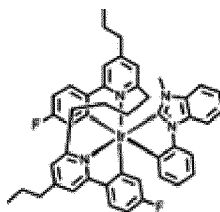
| Compound No. | HOMO (eV) | LUMO (eV) |
|--------------|-----------|-----------|
| BD1 | -5.615 | -2.125 |
| BD8 | -5.648 | -2.120 |
| BD26 | -5.701 | -2.098 |
| ETH7 | -5.99 | -2.75 |

(continued)

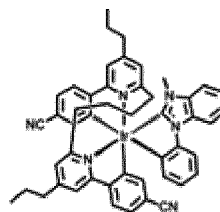
| Compound No. | HOMO (eV) | LUMO (eV) |
|--------------|-----------|-----------|
| HTH26 | -5.51 | -1.91 |
| Compound A | -4.84 | -1.16 |



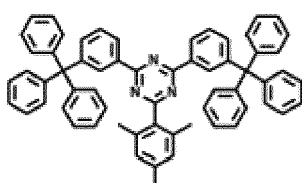
BD1



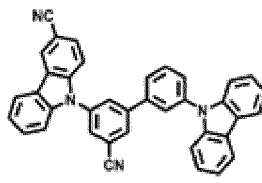
BD8



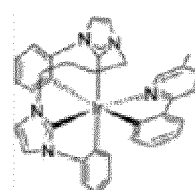
BD26



ETH7



HTH26



Compound A

[0255] Referring to Table 2, it can be seen that Compounds BD1, BD8, BD26, ETH7, and HTH26 had HOMO and LUMO energy levels suitable for the manufacture of an organic light-emitting device.

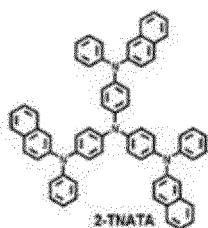
Example 1

[0256] As an anode, a 15 Ω/cm^2 (1,200 Å) glass substrate (a product of Corning Inc.) on which ITO was formed was cut to a size of 50 mm x 50 mm x 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 resultant glass substrate was loaded onto a vacuum deposition apparatus.

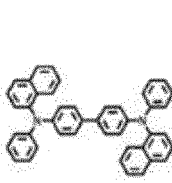
[0257] 2-TNATA was vacuum-deposited on the anode to form a hole injection layer having a thickness of 600 Å, and 4,4'-bis[N-(1-naphthyl)-N-phenyl aminobiphenyl] (hereinafter referred to as NPB) was vacuum-deposited on the hole injection layer to form a hole transport layer having a thickness of 300 Å.

[0258] Compound BD1 as the organometallic compound, Compound ETH7 as the second compound, and Compound HTH26 as the third compound were vacuum-deposited on the hole transport layer to form an emission layer having a thickness of 300 Å. Here, an amount of Compound BD1 was 10 wt% per the total weight (100 wt%) of the emission layer, and a weight ratio of Compound ETH7 and Compound HTH26 was adjusted to 2 : 8.

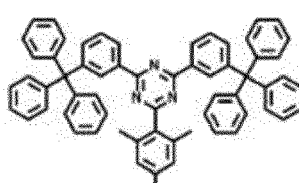
[0259] Compound ETH7 was vacuum-deposited on the emission layer to form a hole blocking layer having a thickness of 50 Å, Alq₃ was vacuum-deposited on the hole blocking layer to form an electron transport layer having a thickness of 300 Å, Yb was vacuum-deposited on the electron transport layer to form an electron injection layer having a thickness of 10 Å, Al was vacuum-deposited on the electron injection layer to form a cathode having a thickness of 3,000 Å, and Compound HT28 was vacuum-deposited on the cathode to form a capping layer having a thickness of 700 Å, thereby completing the manufacture of an organic light-emitting device.



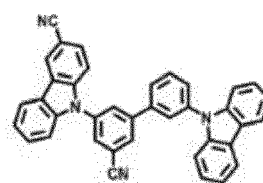
2-TNATA



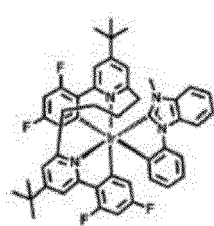
NPB



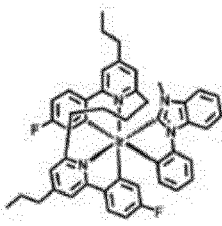
ETH7



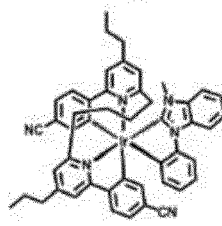
HTH26



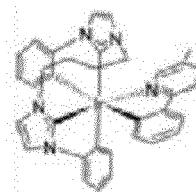
801



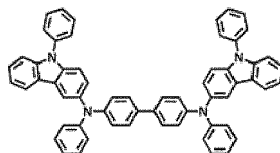
808



8026



Compound A



HT28

Examples 2 and 3 and Comparative Examples 1 to 4

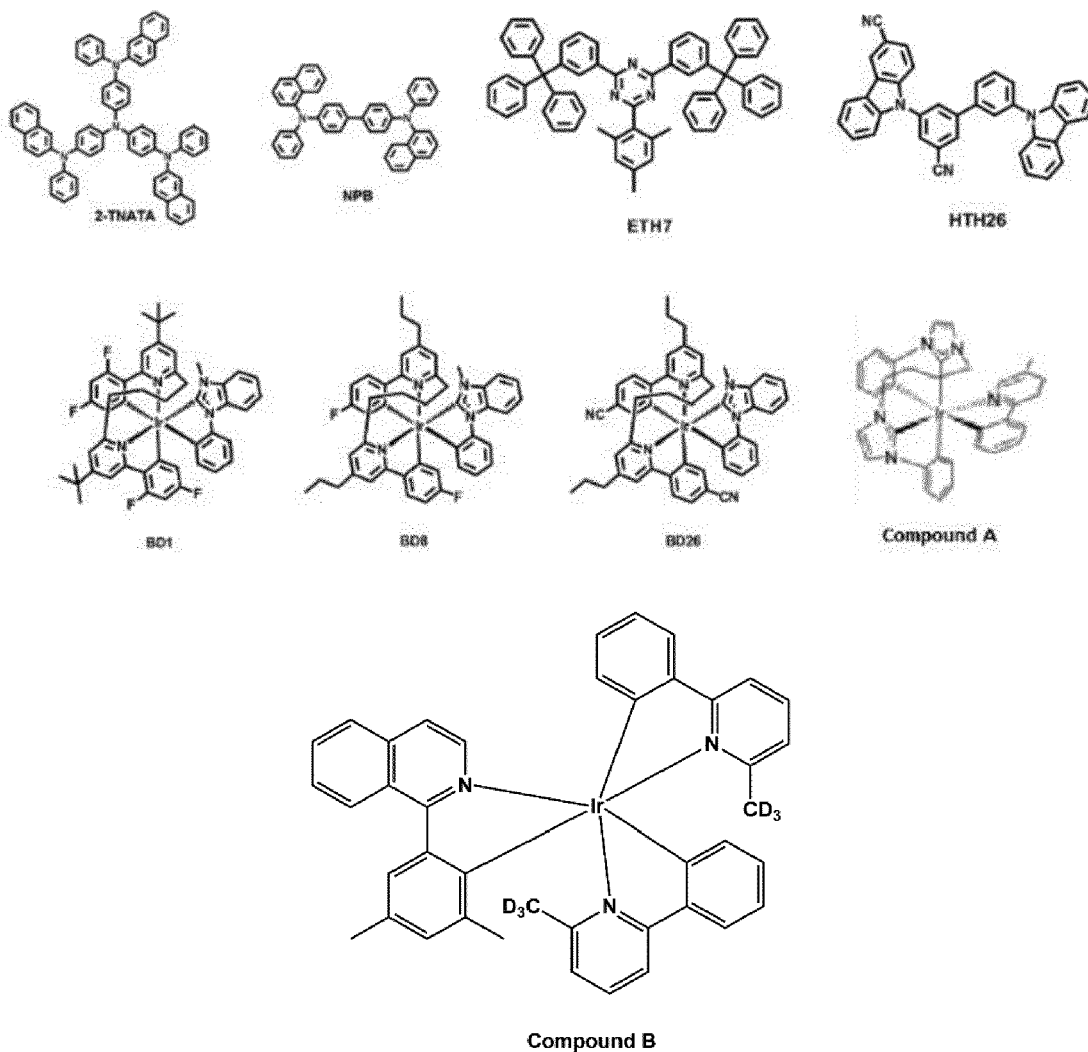
[0260] Organic light-emitting devices were manufactured in substantially the same manner as in Example 1, except that, in forming an emission layer, compounds shown in Table 3 were used instead of each of the organometallic compound, the second compound, and the third compound.

Evaluation Example 2

[0261] The driving voltage (V) at 1,000 cd/m², current density (mA/cm²), and luminescence efficiency (cd/A) of the organic light-emitting devices manufactured according to Examples 1 to 3 and Comparative Examples 1 to 4 were each measured by using Keithley MU 236 and luminance meter R650. In addition, the decay time of delayed fluorescence was evaluated based on the time-resolved spectra of the organic light-emitting devices measured by using the Tektronix TDS 460 Four Channel Digitizing Oscilloscope while applying a voltage pulse by using the AVTECCH AV-1011-B pulse generator (wherein a pulse width was between 100 ns and 1 ms), and the results are shown in Table 3.

Table 3

| | Organometallic compound | Second compound | Third compound | Driving voltage (V) | Current density (mA/cm ²) | Luminance (cd/m ²) | Efficiency (cd/A) | Emission wavelength (nm) | Time-resolved spectrum (μs) |
|-----------------------|-------------------------|-----------------|----------------|---------------------|---------------------------------------|--------------------------------|-------------------|--------------------------|-----------------------------|
| Example 1 | BD1 | ETH7 | HTH26 | 4.3 | 5.3 | 1000 | 18.8 | 469 | 1.6 |
| Example 2 | BD8 | ETH7 | HTH26 | 3.3 | 6.5 | 1000 | 16.5 | 465 | 2.0 |
| Example 3 | BD26 | ETH7 | HTH26 | 3.3 | 4.8 | 1000 | 17.2 | 474 | 1.8 |
| Comparative Example 1 | Compound A | ETH7 | HTH26 | 5.4 | 8.4 | 1000 | 12.1 | 480 | 2.6 |
| Comparative Example 2 | BD1 | - | HTH26 | 5.9 | 5.3 | 1000 | 16.2 | 470 | 1.6 |
| Comparative Example 3 | BD1 | ETH7 | - | 6.8 | 6.5 | 1000 | 12.5 | 470 | 1.6 |
| Comparative Example 4 | Compound B | ETH7 | HTH26 | 6.2 | 8.8 | 1000 | 13.4 | 482 | 2.9 |



[0262] Referring to Table 3, it can be seen that the organic light-emitting devices of Examples 1 to 3 emitted blue light, and compared to the organic light-emitting devices of Comparative Examples 1 to 4, had high efficiency, a long lifespan, and low driving voltage.

[0263] According to the one or more embodiments, an organic light-emitting device may have high luminescence efficiency, high color purity, and a long lifespan.

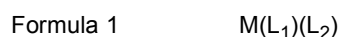
[0264] It should be understood that embodiments described herein should be considered in a descriptive sense only and not for purposes of limitation. Descriptions of features or aspects within each embodiment should typically be considered as available for other similar features or aspects in other embodiments. While one or more embodiments have been described with reference to the figures, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the scope of the present disclosure as defined by the following claims, and equivalents thereof.

Claims

1. An organic light-emitting device comprising:

a first electrode; a second electrode; and an organic layer located between the first electrode and the second electrode and including an emission layer,

wherein the emission layer includes an organometallic compound represented by Formula 1:



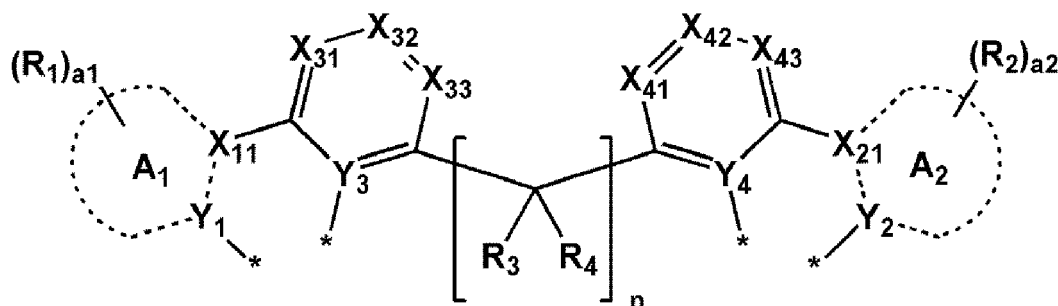
wherein, in Formula 1,

M is selected from iridium (Ir), cobalt (Co), rhodium (Rh), and meitnerium (Mt);

L₁ is a ligand represented by Formula 1-1; and

L₂ is a bidentate organic ligand;

Formula 1-1



wherein, in Formula 1-1, ring A₁ and ring A₂ are each independently selected from a C₅-C₃₀ carbocyclic group and a C₁-C₃₀ heterocyclic group,

Y₁ to Y₄ are each independently selected from N and C,

X₁₁ and X₂₁ are each independently selected from N and C,

X₃₁ is C(R₃₁) or N, X₃₂ is C(R₃₂) or N, X₃₃ is C(R₃₃) or N, X₄₁ is C(R₄₁) or N, X₄₂ is C(R₄₂) or N, and X₄₃ is C(R₄₃) or N,

R₁ to R₄, R₃₁ to R₃₃, and R₄₁ to R₄₃ 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 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 C₇-C₆₀ alkylaryl 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 C₂-C₆₀ alkylheteroaryl group, a substituted or unsubstituted C₁-C₆₀ heteroaryloxy group, a substituted or unsubstituted C₁-C₆₀ heteroarylthio 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),

a₁ and a₂ are each independently an integer from 1 to 10,

n is an integer from 2 to 6,

* indicates a binding site to M,

at least one substituent of the substituted C₁-C₆₀ alkyl group, the substituted C₂-C₆₀ alkenyl group, the substituted C₂-C₆₀ alkynyl group, the substituted C₁-C₆₀ alkoxy group, the substituted C₃-C₁₀ cycloalkyl group, the substituted C₁-C₁₀ heterocycloalkyl group, the substituted C₃-C₁₀ cycloalkenyl group, the substituted C₁-C₁₀ heterocycloalkenyl group, the substituted C₆-C₆₀ aryl group, the substituted C₇-C₆₀ alkylaryl group, the substituted C₆-C₆₀ aryloxy group, the substituted C₆-C₆₀ arylthio group, the substituted C₁-C₆₀ heteroaryl group, the substituted C₂-C₆₀ alkylheteroaryl group, the substituted C₁-C₆₀ heteroaryloxy group, the substituted C₁-C₆₀ heteroarylthio 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 C₇-C₆₀ alkylaryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group,

a C₂-C₆₀ alkylheteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, -O(Q₁₁), -S(Q₁₁), -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 C₇-C₆₀ alkylaryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a C₂-C₆₀ alkylheteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₇-C₆₀ alkylaryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a C₂-C₆₀ alkylheteroaryl 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 C₇-C₆₀ alkylaryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a C₂-C₆₀ alkylheteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, -O(Q₂₁), -S(Q₂₁), -Si(Q₂₁)(Q₂₂)(Q₂₃), -N(Q₂₁)(Q₂₂), -B(Q₂₁)(Q₂₂), -C(=O)(Q₂₁), -S(=O)₂(Q₂₁), and -P(=O)(Q₂₁)(Q₂₂); and

-O(Q₃₁), -S(Q₃₁), -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 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 C₁-C₆₀ alkyl group that is substituted with at least one selected from deuterium, -F, a cyano group, a C₁-C₆₀ alkyl group, a phenyl group, a biphenyl group, and a terphenyl group, and a C₆-C₆₀ aryl group that is substituted with at least one selected from deuterium, -F, a cyano group, a C₁-C₁₀ alkyl group, a phenyl group, and a biphenyl group.

2. An organic light-emitting device according to claim 1, wherein the organic layer includes emission layers in the number of p,
p is an integer of 2 or more, and
two or more emission layers among the emission layers in the number of p comprise the organometallic compound represented by Formula 1.
3. An organic light-emitting device according to claim 1 or claim 2, wherein the emission layer includes a first emission layer to emit a first-color light, a second emission layer to emit a second-color light, and a third emission layer to emit a third-color light,
the first-color light, the second-color light, and the third-color light each have different maximum luminescence wavelengths from each other,
the first-color light is blue, the second-color light is green, and the third-color light is red, and
the first emission layer comprises the organometallic compound represented by Formula 1.
4. An organic light-emitting device according to any one of claims 1 to 3, wherein the emission layer further comprises a second compound and a third compound,
the organometallic compound, the second compound, and the third compound are each different from each other, the second compound and the third compound form an exciplex, and
the organometallic compound and the second compound and/or the third compound do not form an exciplex.
5. An organic light-emitting device according to claim 4, wherein the organometallic compound, the second compound, and the third compound each satisfy <Condition 1> to <Condition 4>:

<Condition 1> Lowest unoccupied molecular orbital (LUMO) energy level (eV) of the third compound is greater than LUMO energy level (eV) of the organometallic compound

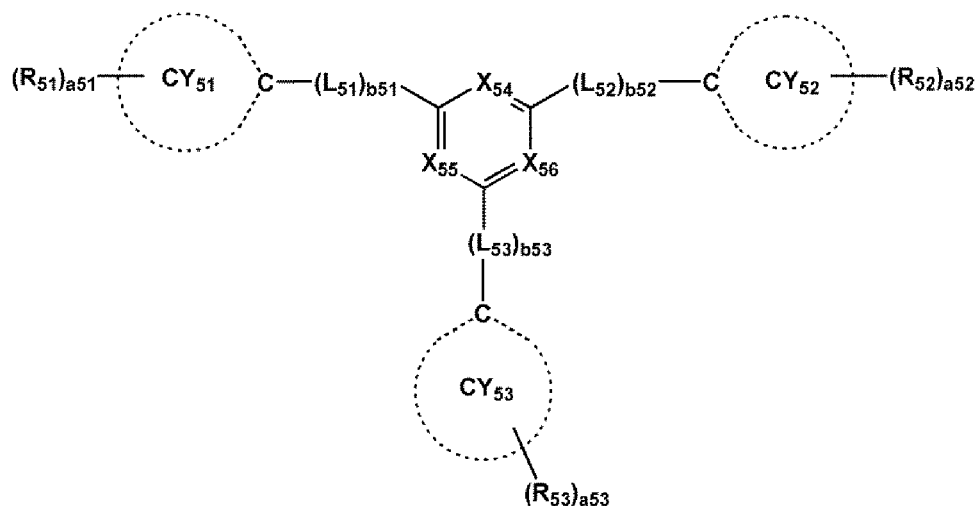
<Condition 2> LUMO energy level (eV) of the organometallic compound is greater than LUMO energy level (eV) of the second compound

<Condition 3> Highest occupied molecular orbital (HOMO) energy level (eV) of the organometallic compound is greater than HOMO energy level (eV) of the third compound

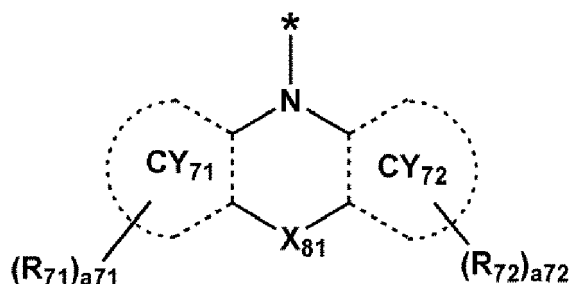
<Condition 4> HOMO energy level (eV) of the third compound is greater than HOMO energy level (eV) of the second compound.

6. An organic light-emitting device according to claim 4 or claim 5, wherein the second compound is represented by Formula 2, and the third compound includes a group represented by Formula 3:

Formula 2



Formula 3



wherein, in Formulae 2 and 3,

ring CY51 to ring CY53, ring CY71, and ring CY72 are each independently selected from a C₅-C₃₀ carbocyclic group and a C₁-C₃₀ heterocyclic group,

L₅₁ to L₅₃ are each independently selected from a substituted or unsubstituted C₅-C₃₀ carbocyclic group and a substituted or unsubstituted C₁-C₃₀ heterocyclic group,

a bond between L₅₁ and ring CY₅₁, a bond between L₅₂ and ring CY₅₂, a bond between L₅₃ ring CY₅₃, a bond between two or more L₅₁(s), a bond between two or more L₅₂(s), a bond between two or more L₅₃(s), a bond between L₅₁ and carbon between X₅₄ and X₅₅ in Formula 2, a bond between L₅₂ and carbon between X₅₄ and X₅₆ in Formula 2, and a bond between L₅₃ and carbon between X₅₅ and X₅₆ in Formula 2 are each a carbon-carbon single bond,

b₅₁ to b₅₃ are each independently an integer from 0 to 5, wherein, when b₅₁ is 0, *-(L₅₁)_{b51}-* is a single bond, when b₅₂ is 0, *-(L₅₂)_{b52}-* is a single bond, and when b₅₃ is 0, *-(L₅₃)_{b53}-* is a single bond,

X₅₄ is N or C(R₅₄), X₅₅ is N or C(R₅₅), X₅₆ is N or C(R₅₆), and at least one selected from X₅₄ to X₅₆ is N,

X₈₁ is a single bond, O, S, N(R₈₁), B(R₈₁), C(R_{81a})(R_{81b}), or Si(R_{81a})(R_{81b}),

R₅₁ to R₅₆, R₇₁, R₇₂, R₈₁, R_{81a}, and R_{81b} 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 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 C₇-C₆₀ alkylaryl 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 C₂-C₆₀ alkylheteroaryl 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),

a51 to a53, a71, and a72 are each independently an integer from 0 to 10,

at least one substituent of the substituted C₅-C₃₀ carbocyclic group, the substituted, a C₁-C₃₀ 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 C₇-C₆₀ alkylaryl group, the substituted C₆-C₆₀ aryloxy group, the substituted C₆-C₆₀ arylthio group, the substituted C₁-C₆₀ heteroaryl group, the substituted C₂-C₆₀ alkylheteroaryl 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 C₇-C₆₀ alkylaryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a C₂-C₆₀ alkylheteroaryl 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 C₇-C₆₀ alkylaryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a C₂-C₆₀ alkylheteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₇-C₆₀ alkylaryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a C₂-C₆₀ alkylheteroaryl 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 C₇-C₆₀ alkylaryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a C₂-C₆₀ alkylheteroaryl 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.

7. An organic light-emitting device according to claim 6, wherein, in Formulae 2 and 3, ring CY₅₁ to ring CY₅₃, ring CY₇₁, and ring CY₇₂ are each independently selected from i) a first ring, ii) a second ring, iii) a condensed ring in which two or more first rings are condensed with each other, iv) a condensed ring in which two or more second rings are condensed with each other, and v) a condensed ring in which one or more first rings and one or more second

rings are condensed with each other,

the first ring is selected from a cyclopentane group, a cyclopentadiene group, a furan group, a thiophene group, a pyrrole group, a silole group, an oxazole group, an isoxazole group, an oxadiazole group, an isoxadiazole group, an oxatriazole group, an isoxatriazole group, a thiazole group, an isothiazole group, a thiadiazole group, an isothiadiazole group, a thiatriazole group, an isothiatriazole group, a pyrazole group, an imidazole group, a triazole group, a tetrazole group, an azasilole group, a diazasilole group, and a triazasilole group, and

the second ring is selected from an adamantane group, a norbornane group, a norbornene group, a cyclohexane group, a cyclohexene group, a benzene group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a triazine group, an oxasilene group, a thiasilene group, a dihydroazasilene group, a dihydrodisilene group, a dihydrosilene group, a dioxine group, an oxathiine group, an oxazine group, a pyran group, a dithiine group, a thiazine group, a thiopyran group, a cyclohexadiene group, a dihydropyridine group, and a dihydropyrazine group.

8. An organic light-emitting device according to claim 6 or claim 7, wherein, in Formulae 2 and 3, R₅₁ to R₅₆, R₇₁, R₇₂, R₈₁, R_{81a}, and R_{81b} 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, and a C₁-C₆₀ alkoxy group;

a C₁-C₆₀ alkyl group and a C₁-C₆₀ alkoxy group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, -CD₃, -CD₂H, -CDH₂, -CF₃, -CF₂H, -CFH₂, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group;

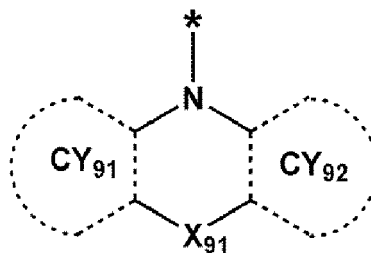
a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, an 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 perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl 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 benzoquinolinyl group, a benzoisoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, a benzoisothiazolyl group, a benzoxazolyl group, a benzoisoxazolyl group, a triazolyl group, a tetrazolyl group, a thiadiazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphtho silolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafluorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indeno carbazolyl group, and an indolocarbazolyl group;

a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl 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 perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl 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 benzoquinolinyl group, a benzoisoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl

group, a benzoisothiazolyl group, a benzoxazolyl group, a benzoisoxazolyl group, a triazolyl group, a tetrazolyl group, a thiadiazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphthosilolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafluorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indeno carbazolyl group, an indolocarbazolyl group, and a group represented by Formula 91, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, -CD₃, -CD₂H, -CDH₂, -CF₃, -CF₂H, -CFH₂, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₁-C₆₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl 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 perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl 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 benzoquinolinyl group, a benzoisoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, a benzoisothiazolyl group, a benzoxazolyl group, a benzoisoxazolyl group, a triazolyl group, a tetrazolyl group, a thiadiazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphthosilolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafluorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indeno carbazolyl group, an indolocarbazolyl group, -Si(Q₃₁)(Q₃₂)(Q₃₃), -N(Q₃₁)(Q₃₂), -B(Q₃₁)(Q₃₂), -C(=O)(Q₃₁), -S(=O)₂(Q₃₁), and -P(=O)(Q₃₁)(Q₃₂); and

-Si(Q₁)(Q₂)(Q₃), -N(Q₁)(Q₂), -B(Q₁)(Q₂), -C(=O)(Q₁), -S(=O)₂(Q₁), and -P(=O)(Q₁)(Q₂), and Q₁ to Q₃ 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 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 C₁-C₆₀ alkyl group that is substituted with at least one selected from deuterium, -F, a cyano group, a C₁-C₆₀ alkyl group, a phenyl group, and a biphenyl group, a C₆-C₆₀ aryl group that is substituted with at least one selected from deuterium, -F, a cyano group, a C₁-C₁₀ alkyl group, a phenyl group, and a biphenyl group, and a C₁-C₆₀ heteroaryl group that is substituted with at least one selected from deuterium, -F, a cyano group, a C₁-C₁₀ alkyl group, a phenyl group, and a biphenyl group:

Formula 91



wherein, in Formula 91,

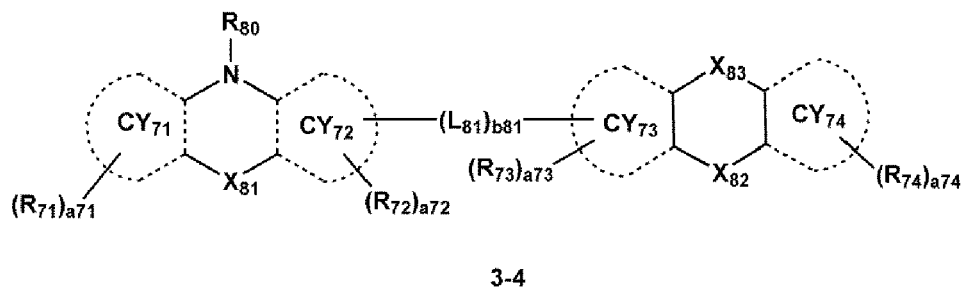
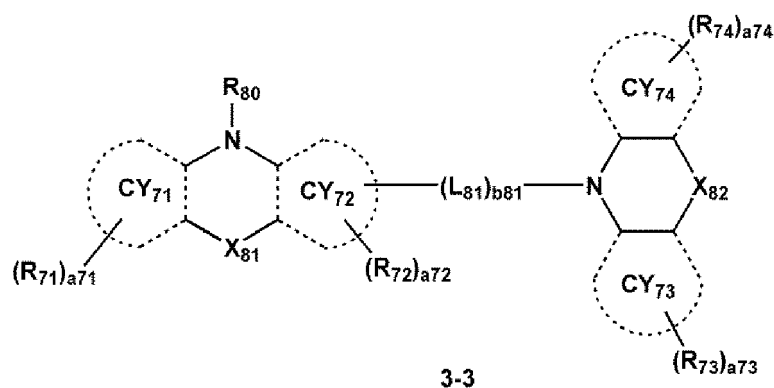
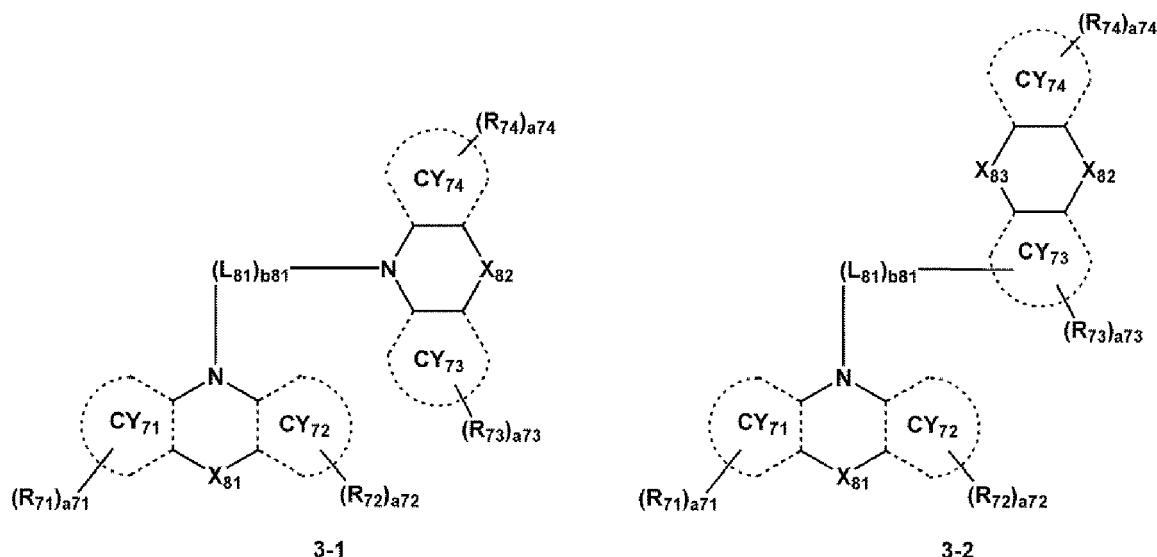
ring CY₉₁ and ring CY₉₂ are each independently selected from a C₅-C₃₀ carbocyclic group and a C₁-C₃₀ heterocyclic group,

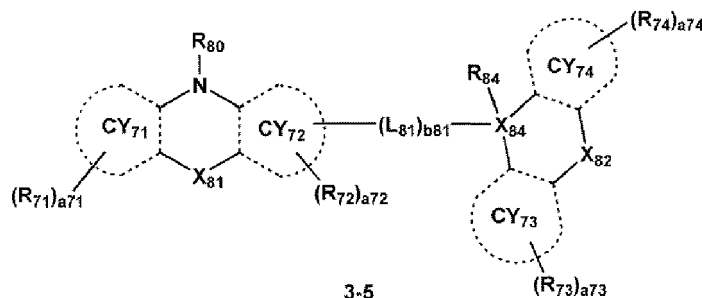
X₉₁ is a single bond, O, S, N(R₉₁), B(R₉₁), C(R_{91a})(R_{91b}), or Si(R_{91a})(R_{91b}),

R₉₁, R_{91a}, and R_{91b} are each independently the same as described in connection with R₈₁, R_{81a}, and R_{81b}, respectively, in claim 6, and

* indicates a binding site to a neighboring atom.

9. An organic light-emitting device according to any one of claims 6 to 8, wherein the third compound is represented by one of Formulae 3-1 to 3-5:





wherein, in Formulae 3-1 to 3-5,

ring CY₇₁, ring CY₇₂, X₈₁, R₇₁, R₇₂, a₇₁, and a₇₂ are each independently the same as described in claim 6,
ring CY₇₃, ring CY₇₄, R₇₃, R₇₄, a₇₃, and a₇₄ are each independently the same as described in connection with
ring CY₇₁, ring CY₇₂, R₇₁, R₇₂, a₇₁, and a₇₂, respectively, in claim 6,

L₈₁ is selected from *-C(Q₄)(Q₅)-*, *-Si(Q₄)(Q₅)-*, a substituted or unsubstituted C₅-C₃₀ carbocyclic group,
and a substituted or unsubstituted C₁-C₃₀ heterocyclic group, wherein Q₄ and Q₅ are each independently the
same as described in connection with Q₁ in claim 6,

b₈₁ is an integer from 0 to 5, wherein, when b₈₁ is 0, *-(L₈₁)_{b81}-* is a single bond, and when b₈₁ is 2 or more,
two or more L₈₁(s) are identical to or different from each other,

X₈₂ is a single bond, O, S, N(R₈₂), B(R₈₂), C(R_{82a})(R_{82b}), or Si(R_{82a})(R_{82b}),

X₈₃ is a single bond, O, S, N(R₈₃), B(R₈₃), C(R_{83a})(R_{83b}), or Si(R_{83a})(R_{83b}),

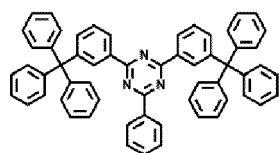
in Formulae 3-2 and 3-4, X₈₂ and X₈₃ are not each a single bond at the same time,

X₈₄ is C or Si,

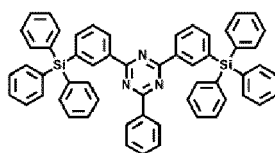
R₈₀, R₈₂, R₈₃, R_{82a}, R_{82b}, R_{83a}, R_{83b}, and R₈₄ are each independently the same as described in connection
with R₈₁ in claim 6, and

* and * each indicate a binding site to a neighboring atom.

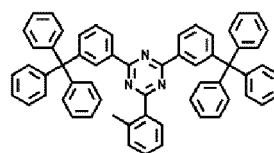
10. The organic light-emitting device of claim 6, wherein the second compound is selected from Compounds ETH1 to
ETH80, and
the third compound is selected from Compounds HTH1 to HTH28, and



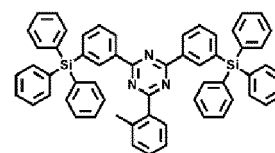
ETH1



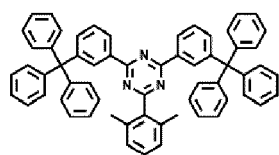
ETH2



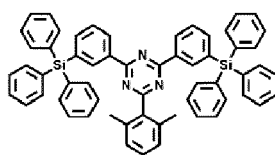
ETH3



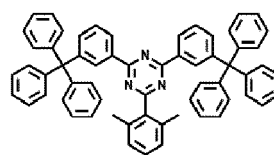
ETH4



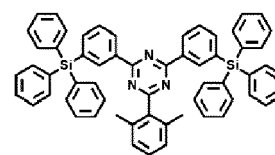
ETH5



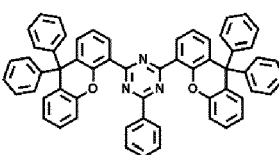
ETH6



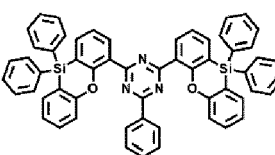
ETH7



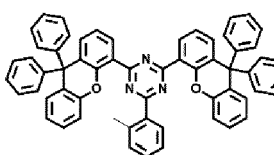
ETH8



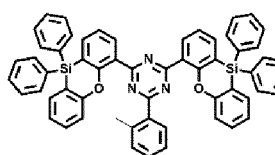
ETH9



ETH10

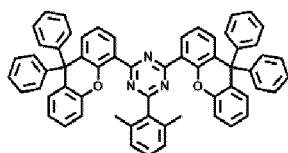


ETH11

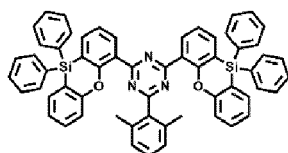


ETH12

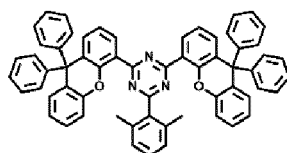
5



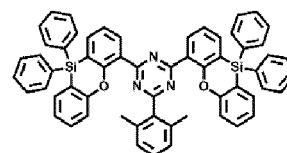
ETH13



ETH14

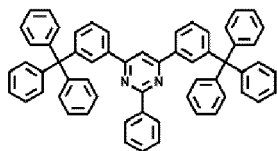


ETH15

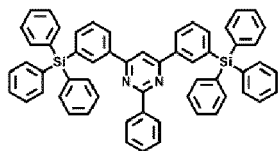


ETH16

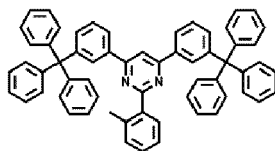
10



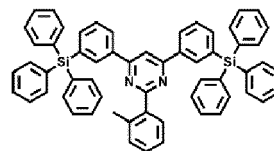
ETH17



ETH18

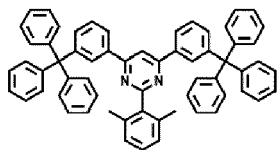


ETH19

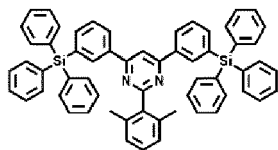


ETH20

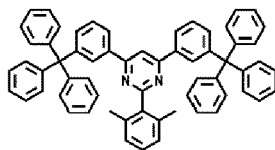
15



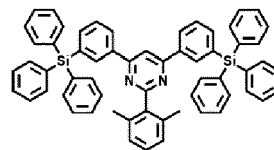
ETH21



ETH22

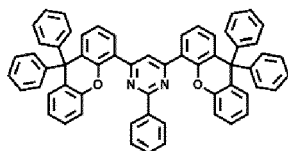


ETH23

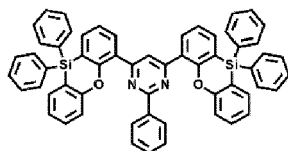


ETH24

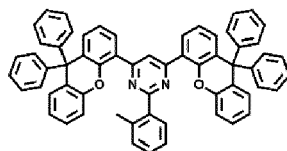
20



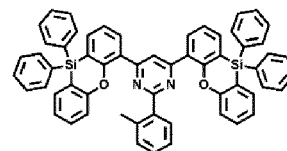
ETH25



ETH26



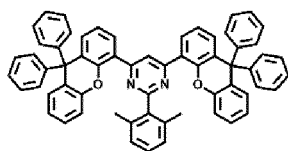
ETH27



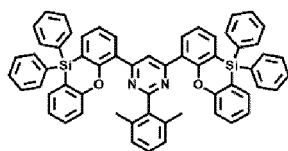
ETH28

25

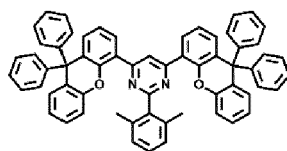
30



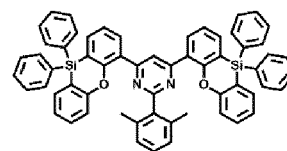
ETH29



ETH30



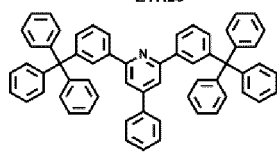
ETH31



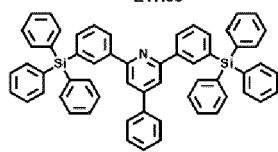
ETH32

35

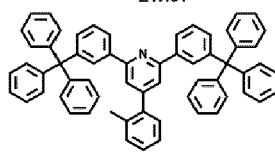
40



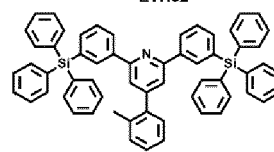
ETH33



ETH34

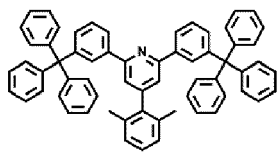


ETH35

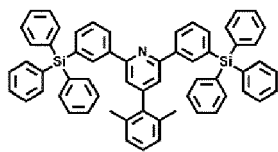


ETH36

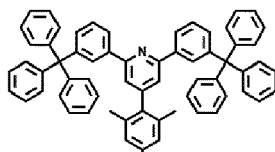
45



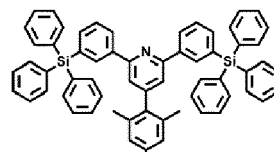
ETH37



ETH38



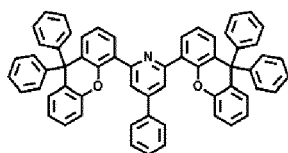
ETH39



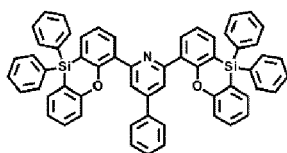
ETH40

50

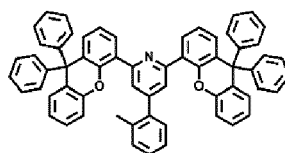
55



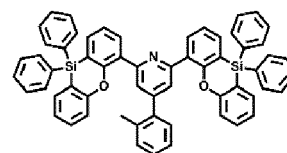
ETH41



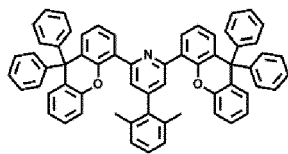
ETH42



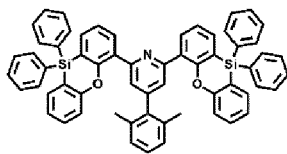
ETH43



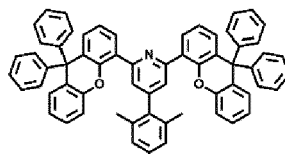
ETH44



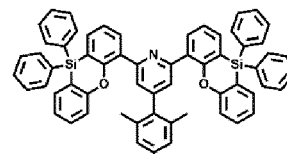
ETH45



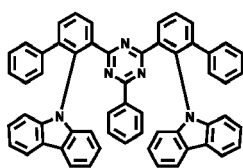
ETH46



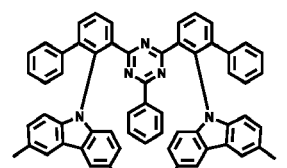
ETH47



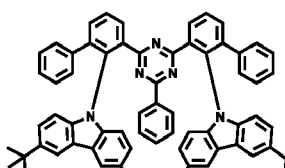
ETH48



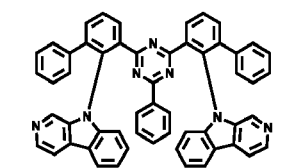
ETH49



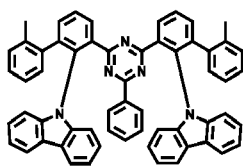
ETH50



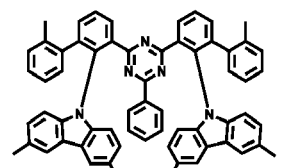
ETH51



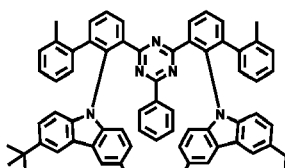
ETH52



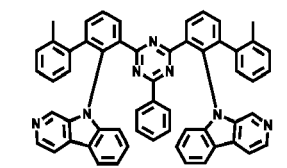
ETH53



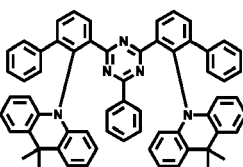
ETH54



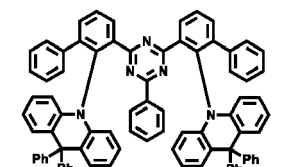
ETH55



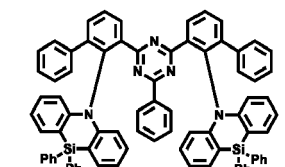
ETH56



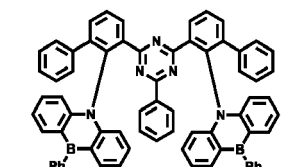
ETH57



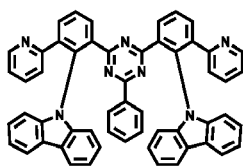
ETH58



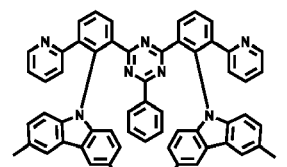
ETH59



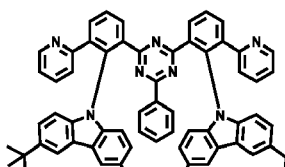
ETH60



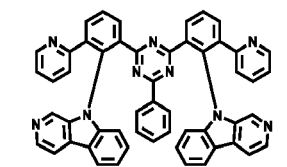
ETH61



ETH62

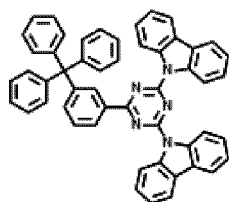


ETH63

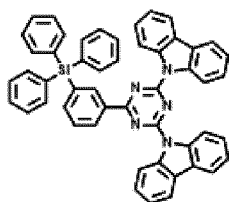


ETH64

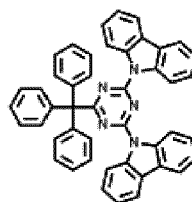
5



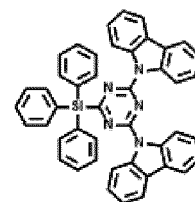
ETH65



ETH66

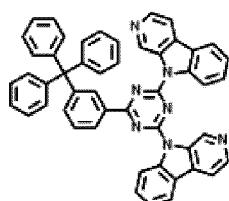


ETH67

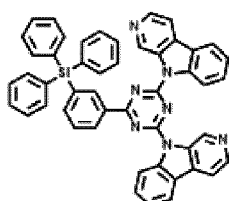


ETH68

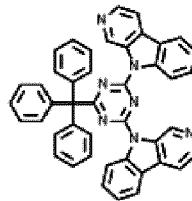
10



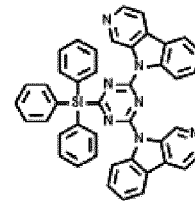
ETH69



ETH70

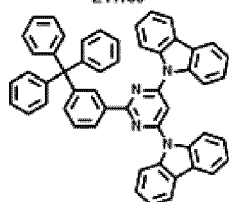


ETH71

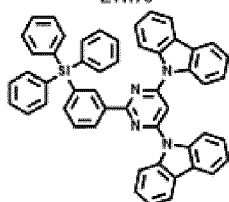


ETH72

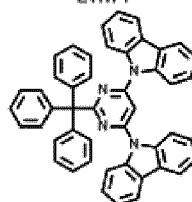
15



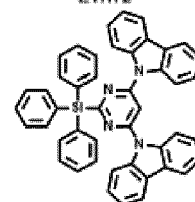
ETH73



ETH74

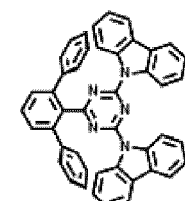


ETH75

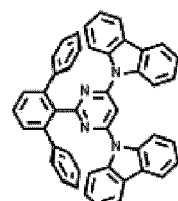


ETH76

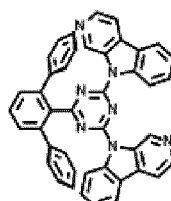
25



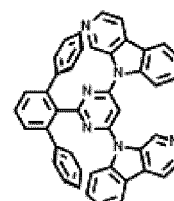
ETH77



ETH78

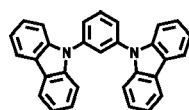


ETH79

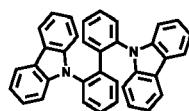


ETH80

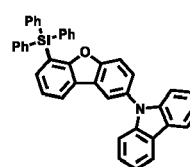
35



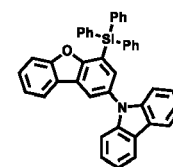
HTH1



HTH2

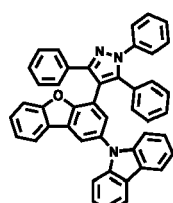


HTH3

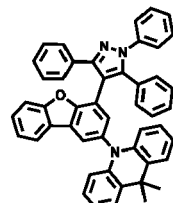


HTH4

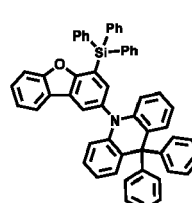
40



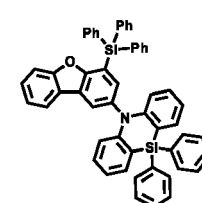
HTH5



HTH6



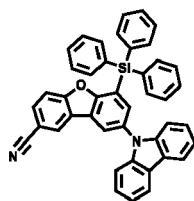
HTH7



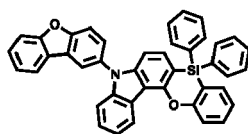
HTH8

50

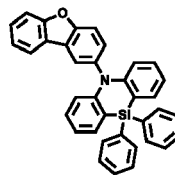
55



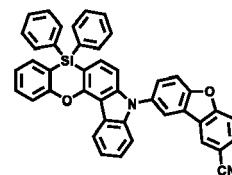
HTH9



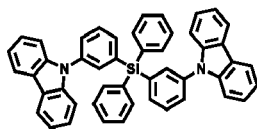
HTH10



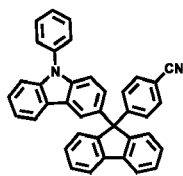
HTH11



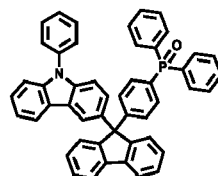
HTH12



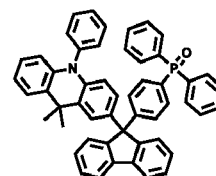
HTH13



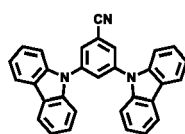
HTH14



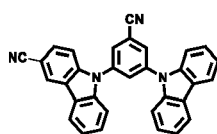
HTH15



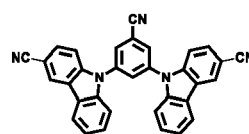
HTH16



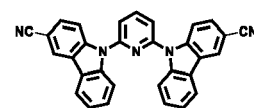
HTH17



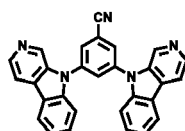
HTH18



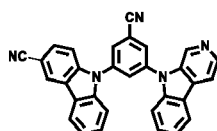
HTH19



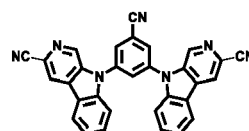
HTH20



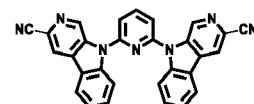
HTH21



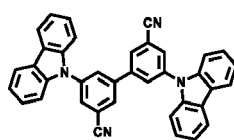
HTH22



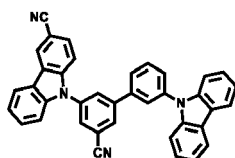
HTH23



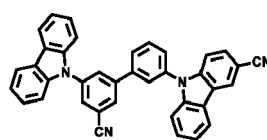
HTH24



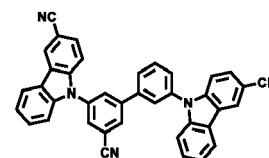
HTH25



HTH26



HTH27



HTH28

11. An organometallic compound represented by Formula 1:

Formula 1

$M(L_1)(L_2)$

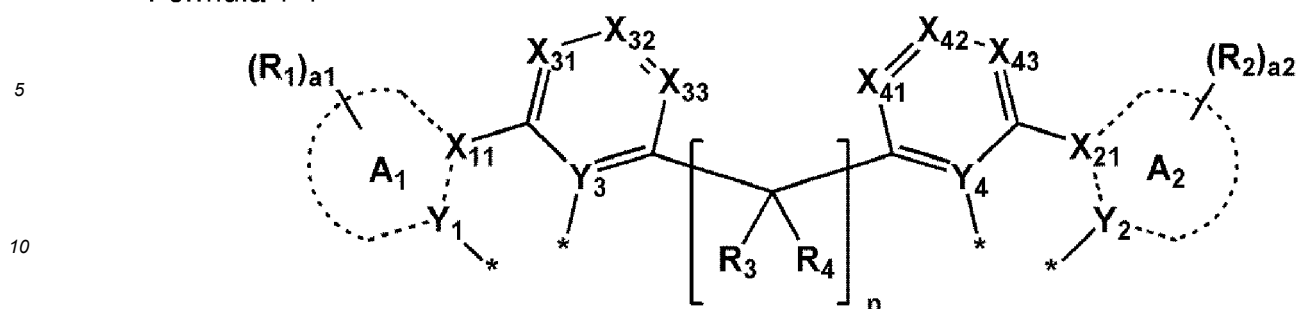
wherein, in Formula 1,

M is selected from iridium (Ir), cobalt (Co), rhodium (Rh), and meitnerium (Mt);

L_1 is a ligand represented by Formula 1-1; and

L_2 is a bidentate organic ligand,

Formula 1-1



wherein, in Formula 1-1, ring A₁ and ring A₂ are each independently selected from a C₅-C₃₀ carbocyclic group and a C₁-C₃₀ heterocyclic group,

Y₁ to Y₄ are each independently selected from N and C,

X₁₁ and X₂₁ are each independently selected from N and C,

X₃₁ is C(R₃₁) or N, X₃₂ is C(R₃₂) or N, X₃₃ is C(R₃₃) or N, X₄₁ is C(R₄₁) or N, X₄₂ is C(R₄₂) or N, and X₄₃ is C(R₄₃) or N,

R₁ to R₄, R₃₁ to R₃₃, and R₄₁ to R₄₃ 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 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 C₇-C₆₀ alkylaryl 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 C₂-C₆₀ alkylheteroaryl group, a substituted or unsubstituted C₁-C₆₀ heteroaryloxy group, a substituted or unsubstituted C₁-C₆₀ heteroarylthio 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),

a₁ and a₂ are each independently an integer from 1 to 10,

n is an integer from 2 to 6,

* indicates a binding site to M,

at least one substituent of the substituted C₁-C₆₀ alkyl group, the substituted C₂-C₆₀ alkenyl group, the substituted C₂-C₆₀ alkynyl group, the substituted C₁-C₆₀ alkoxy group, the substituted C₃-C₁₀ cycloalkyl group, the substituted C₁-C₁₀ heterocycloalkyl group, the substituted C₃-C₁₀ cycloalkenyl group, the substituted C₁-C₁₀ heterocycloalkenyl group, the substituted C₆-C₆₀ aryl group, the substituted C₇-C₆₀ alkylaryl group, the substituted C₆-C₆₀ aryloxy group, the substituted C₆-C₆₀ arylthio group, the substituted C₁-C₆₀ heteroaryl group, the substituted C₂-C₆₀ alkylheteroaryl group, the substituted C₁-C₆₀ heteroaryloxy group, the substituted C₁-C₆₀ heteroarylthio 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 C₇-C₆₀ alkylaryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a C₂-C₆₀ alkylheteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, -O(Q₁₁), -S(Q₁₁), -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 C₇-C₆₀ alkylaryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a C₂-C₆₀ alkylheteroaryl group, a monovalent non-aromatic

condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;
 a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₇-C₆₀ alkylaryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a C₂-C₆₀ alkylheteroaryl 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 C₇-C₆₀ alkylaryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a C₂-C₆₀ alkylheteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, -O(Q₂₁), -S(Q₂₁), -Si(Q₂₁)(Q₂₂)(Q₂₃), -N(Q₂₁)(Q₂₂), -B(Q₂₁)(Q₂₂), -C(=O)(Q₂₁), -S(=O)₂(Q₂₁), and -P(=O)(Q₂₁)(Q₂₂); and -O(Q₃₁), -S(Q₃₁), -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 C₇-C₆₀ alkylaryl 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 C₁-C₆₀ alkyl group that is substituted with at least one selected from deuterium, -F, a cyano group, a C₁-C₆₀ alkyl group, a phenyl group, a biphenyl group, and a terphenyl group, and a C₆-C₆₀ aryl group that is substituted with at least one selected from deuterium, -F, a cyano group, a C₁-C₁₀ alkyl group, a phenyl group, and a biphenyl group.

12. An organometallic compound according to claim 11, wherein ring A₁ and ring A₂ are each independently selected from i) a first ring, ii) a second ring, iii) a condensed ring in which two or more first rings are condensed with each other, iv) a condensed ring in which two or more second rings are condensed with each other, and v) a condensed ring in which one or more first rings and one or more second rings are condensed with each other,

the first ring is selected from a cyclopentane group, a cyclopentene group, a cyclopentadiene group, a furan group, a thiophene group, a pyrrole group, a borole group, a phosphole group, a silole group, a germole group, a selenophene group, an oxazole group, an isoxazole group, an oxadiazole group, an isoxadiazole group, an oxatriazole group, an isoxatriazole group, a thiazole group, an isothiazole group, a thiadiazole group, an isothiadiazole group, a thia-triazole group, an isothiatriazole group, a pyrazole group, an imidazole group, a triazole group, a tetrazole group, an azasilole group, a diazasilole group, and a triazasilole group, and

the second ring is selected from a cyclohexane group, a cyclohexene group, a cyclohexadiene group, an adamantane group, a norbornane group, a norbornene group, a benzene group, a pyridine group, a dihydropyridine group, a tetrahydropyridine group, a pyrimidine group, a dihydropyrimidine group, a tetrahydropyrimidine group, a pyrazine group, a dihydropyrazine group, a tetrahydropyrazine group, a pyridazine group, a dihydropyridazine group, a tetrahydropyridazine group, a triazine group, an oxasiline group, a thiasiline group, a dihydroazasiline group, a dihydrodisililene group, a dihydrosililene group, a dioxine group, an oxathiine group, an oxazine group, a pyran group, a dithiine group, a thiazine group, and a thiopyran group.

13. An organometallic compound according to claim 11 or claim 12, wherein two selected from Y₁ to Y₄ are each N, and the other two are each C.

14. An organometallic compound according to any one of claims 11 to 13, wherein R₁ to R₄, R₃₁ to R₃₃, and R₄₁ to R₄₃ 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, and a C₁-C₆₀ alkoxy group;
 a C₁-C₆₀ alkyl group and a C₁-C₆₀ alkoxy group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, -CD₃, -CD₂H, -CDH₂, -CF₃, -CF₂H, -CFH₂, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a biphenyl group, a naphthyl group, a

pyridinyl group, and a pyrimidinyl group;

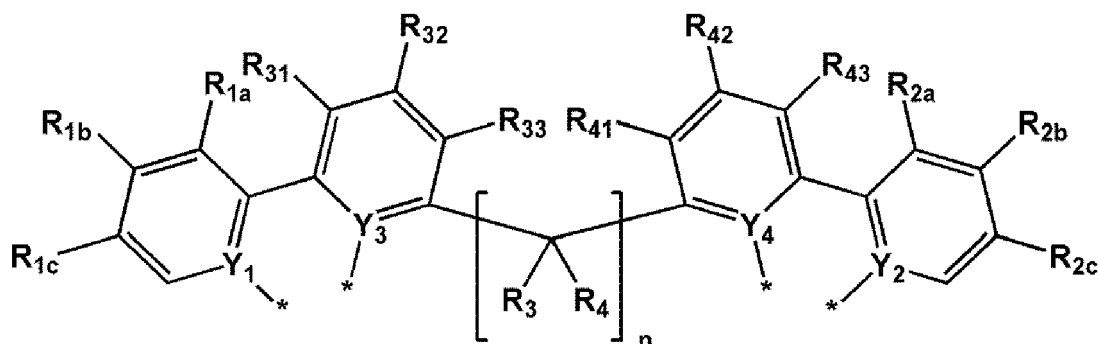
a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, an 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 perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl 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 benzoquinolinyl group, a benzoisoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, a benzoisothiazolyl group, a benzoxazolyl group, a benzoisoxazolyl group, a triazolyl group, a tetrazolyl group, a thiadiazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphtho silolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafluorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indeno carbazolyl group, and an indolocarbazolyl group;

a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl 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 perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl 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 benzoquinolinyl group, a benzoisoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, a benzoisothiazolyl group, a benzoxazolyl group, a benzoisoxazolyl group, a triazolyl group, a tetrazolyl group, a thiadiazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphtho silolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafluorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indeno carbazolyl group, and an indolocarbazolyl group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, -CD₃, -CD₂H, -CDH₂, -CF₃, -CF₂H, -CFH₂, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₁-C₆₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl 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 perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl 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 benzoquinolinyl group, a benzoisoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phen-

anthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, a benzoisothiazolyl group, a benzoxazolyl group, a benzoisoxazolyl group, a triazolyl group, a tetrazolyl group, a thiadiazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphthosilolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafluorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indeno carbazolyl group, an indolocarbazolyl group, -Si(Q₃₁)(Q₃₂)(Q₃₃), -N(Q₃₁)(Q₃₂), -B(Q₃₁)(Q₃₂), -C(=O)(Q₃₁), -S(=O)₂(Q₃₁), and -P(=O)(Q₃₁)(Q₃₂); and -Si(Q₁)(Q₂)(Q₃), -N(Q₁)(Q₂), -B(Q₁)(Q₂), -C(=O)(Q₁), -S(=O)₂(Q₁), and -P(=O)(O₁)(O₂), and Q₁ to Q₃ 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 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 C₁-C₆₀ alkyl group that is substituted with at least one selected from deuterium, -F, a cyano group, a C₁-C₆₀ alkyl group, a phenyl group, and a biphenyl group, a C₆-C₆₀ aryl group that is substituted with at least one selected from deuterium, -F, a cyano group, a C₁-C₁₀ alkyl group, a phenyl group, and a biphenyl group, and a C₁-C₆₀ heteroaryl group that is substituted with at least one selected from deuterium, -F, a cyano group, a C₁-C₁₀ alkyl group, a phenyl group, and a biphenyl group.

15. An organometallic compound according to any one of claims 11 to 14, wherein L₁ is a ligand represented by Formula 1-1A:

Formula 1-1A



wherein, in Formula 1-1A,

Y₁, Y₂, Y₃, Y₄, n, R₃, R₄, R₃₁, R₃₂, R₃₃, R₄₁, R₄₂, and R₄₃ are each independently the same as described in claim 11,

R_{1a}, R_{1b}, and R_{1c} are each independently the same as described in connection with R₁ in claim 11,

R_{2a}, R_{2b}, and R_{2c} are each independently the same as described in connection with R₂ in claim 11, and

R₃₂ and R₄₂ are the same as each other.

16. An organometallic compound according to claim 15, wherein R_{1a}, R_{1c}, R_{2a}, and R_{2c} are each independently selected from:

hydrogen, deuterium, -F, -Cl, -Br, -I, a cyano group, and a C₁-C₁₀ alkyl group;

a C₁-C₁₀ alkyl group substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, -CD₃, -CD₂H, -CDH₂, -CF₃, -CF₂H, -CFH₂, and a cyano group;

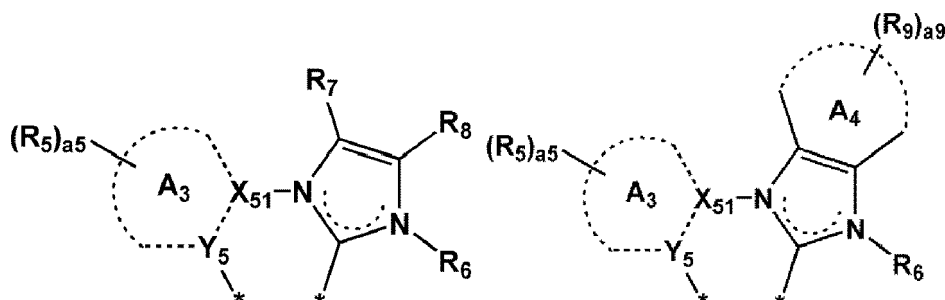
a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a

cyclopentenyl group, a cyclohexenyl group, a phenyl group, and a biphenyl group; and a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, and a biphenyl group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, -CD₃, -CD₂H, -CDH₂, -CF₃, -CF₂H, -CFH₂, a cyano group, a C₁-C₁₀ alkyl group, a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, and a biphenyl group.

17. An organometallic compound according to any one of claims 11 to 16, wherein L₂ is a ligand represented by Formula 1-2A or 1-2B:

Formula 1-2A

Formula 1-2B



wherein, in Formulae 1-2A and 1-2B,

A₃ and A₄ are each independently selected from a C₅-C₃₀ carbocyclic group and a C₁-C₃₀ heterocyclic group, Y₅ is C or N,

X₅₁ is C or N,

R₅, R₆, R₇, R₈, and R₉ 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 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 C₇-C₆₀ alkylaryl 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 C₂-C₆₀ alkylheteroaryl group, a substituted or unsubstituted C₁-C₆₀ heteroaryloxy group, a substituted or unsubstituted C₁-C₆₀ heteroarylthio 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),

a₅ is an integer from 0 to 10, and

a₉ is an integer from 1 to 10.

18. An organometallic compound according to claim 17, wherein ring A₃ and ring A₄ are each independently selected from i) a first ring, ii) a second ring, iii) a condensed ring in which two or more first rings are condensed with each other, iv) a condensed ring in which two or more second rings are condensed with each other, and v) a condensed ring in which one or more first rings and one or more second rings are condensed with each other, the first ring is selected from a cyclopentane group, a cyclopentene group, a cyclopentadiene group, a furan group, a thiophene group, a pyrrole group, a borole group, a phosphole group, a silole group, a germole group, a selenophene group, an oxazole group, an isoxazole group, an oxadiazole group, an isoxadiazole group, an oxatriazole group, an isoxatriazole group, a thiazole group, an isothiazole group, a thiadiazole group, an isothiadiadiazole group, a thia-triazole group, an isothiatriazole group, a pyrazole group, an imidazole group, a triazole group, a tetrazole group, an azasilole group, a diazasilole group, and a triazasilole group, and the second ring is selected from a cyclohexane group, a cyclohexene group, a cyclohexadiene group, an adamantane group, a norbornane group, a norbornene group, a benzene group, a pyridine group, a dihydropyridine group, a tetrahydropyridine group, a pyrimidine group, a dihydropyrimidine group, a tetrahydropyrimidine group, a pyrazine group, a dihydropyrazine group, a tetrahydropyrazine group, a pyridazine group, a dihydropyridazine group, a tetrahydropyridazine group, a triazine group, an oxasiline group, a thiasiline group, a dihydroazasiline group, a dihy-

drodisilane group, a dihydrosilane group, a dioxine group, an oxathiine group, an oxazine group, a pyran group, a dithiine group, a thiazine group, and a thiopyran group.

19. An organometallic compound according to claim 17 or claim 18, wherein R₅, R₆, R₇, R₈, and R₉ 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, and a C₁-C₆₀ alkoxy group;

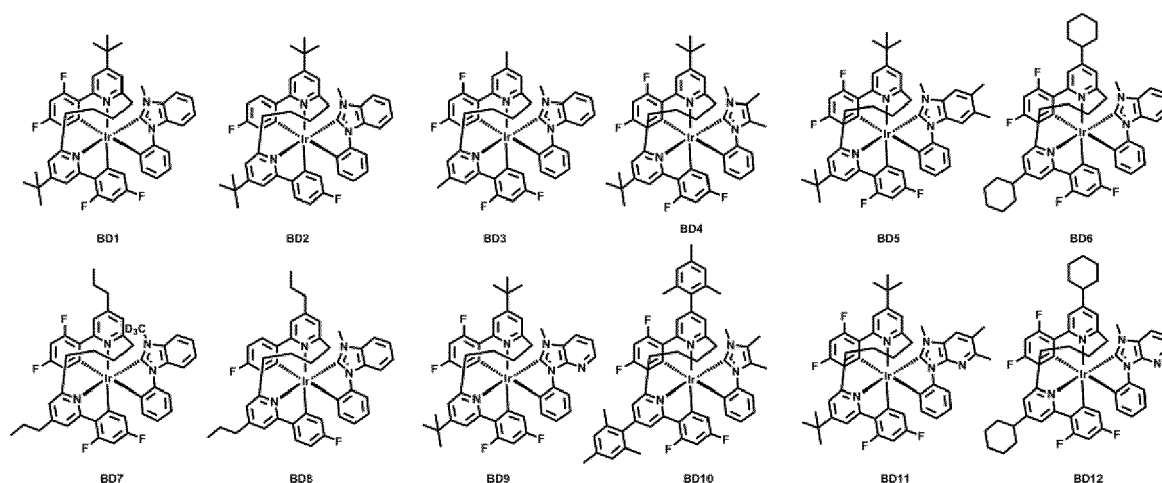
a C₁-C₆₀ alkyl group and a C₁-C₆₀ alkoxy group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, -CD₃, -CD₂H, -CDH₂, -CF₃, -CF₂H, -CFH₂, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a pyridinyl group, and a pyrimidinyl group;

a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl 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 perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl 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 benzoquinolinyl group, a benzoisoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, a benzoisothiazolyl group, a benzoxazolyl group, a benzoisoxazolyl group, a triazolyl group, a tetrazolyl group, a thiadiazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphtho silolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafluorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indeno carbazolyl group, and an indolocarbazolyl group;

a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl 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 perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl 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 benzoquinolinyl group, a benzoisoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, a benzoisothiazolyl group, a benzoxazolyl group, a benzoisoxazolyl group, a triazolyl group, a tetrazolyl group, a thiadiazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphtho silolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafluorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indeno carbazolyl group, and an indolocarbazolyl group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, -CD₃, -CD₂H, -CDH₂, -CF₃, -CF₂H, -CFH₂, a hydroxyl group, a cyano group, a nitro group, an amidino group, a

hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₁-C₆₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl 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 perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl 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 quinoliny group, an isoquinoliny group, a benzoquinoliny group, a benzoisoquinoliny group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnoliny group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, a benzoisothiazolyl group, a benzoxazolyl group, a benzoisoxazolyl group, a triazolyl group, a tetrazolyl group, a thiadiazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphthosilolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafluorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indeno carbazolyl group, an indolocarbazolyl group, -Si(Q₃₁)(Q₃₂)(Q₃₃), -N(Q₃₁)(Q₃₂), -B(Q₃₁)(Q₃₂), -C(=O)(Q₃₁), -S(=O)₂(Q₃₁), and -P(=O)(Q₃₁)(Q₃₂); and -Si(Q₁)(Q₂)(Q₃), -N(Q₁)(Q₂), -B(Q₁)(Q₂), -C(=O)(Q₁), -S(=O)₂(Q₁), and -P(=O)(Q₁)(Q₂), and Q₁ to Q₃ 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 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 C₁-C₆₀ alkyl group that is substituted with at least one selected from deuterium, -F, a cyano group, a C₁-C₆₀ alkyl group, a phenyl group, and a biphenyl group, a C₆-C₆₀ aryl group that is substituted with at least one selected from deuterium, -F, a cyano group, a C₁-C₁₀ alkyl group, a phenyl group, and a biphenyl group, and a C₁-C₆₀ heteroaryl group that is substituted with at least one selected from deuterium, -F, a cyano group, a C₁-C₁₀ alkyl group, a phenyl group, and a biphenyl group.

20. An organometallic compound according to claim 11, wherein the organometallic compound represented by Formula 1 is selected from Compounds BD1 to BD36:



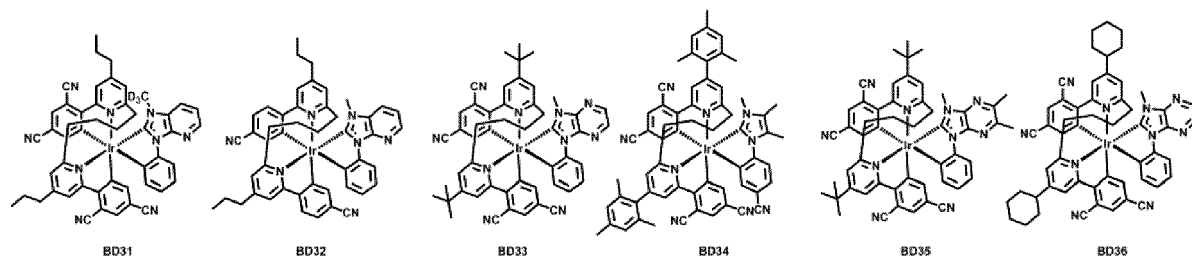
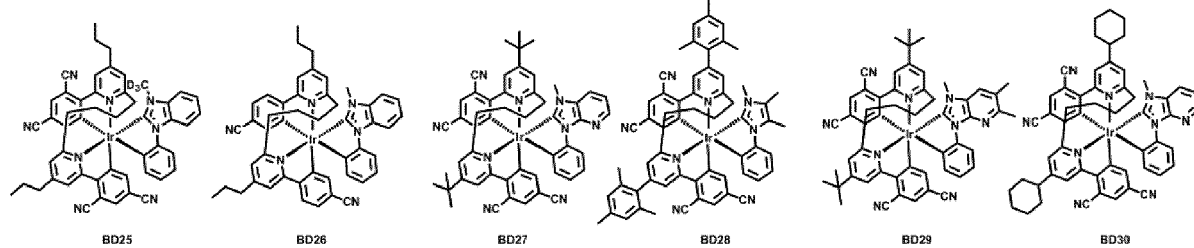
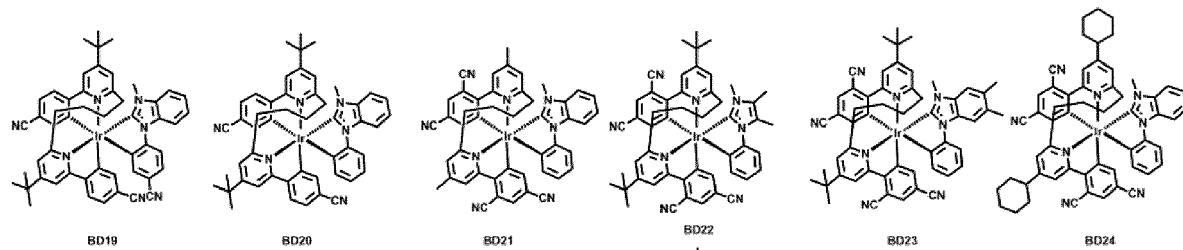
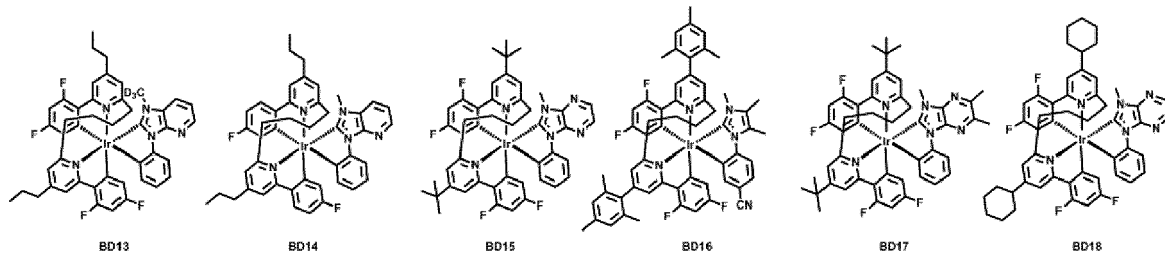


FIG. 1

10

| |
|------------|
| 190 |
| 150 |
| 110 |

FIG. 2

20

| |
|------------|
| 190 |
| 150 |
| 110 |
| 210 |

FIG. 3

30

| |
|------------|
| 220 |
| 190 |
| 150 |
| 110 |

FIG. 4

40

| |
|------------|
| 220 |
| 190 |
| 150 |
| 110 |
| 210 |



EUROPEAN SEARCH REPORT

Application Number
EP 21 15 9535

5

10

15

20

25

30

35

40

45

50

55

| DOCUMENTS CONSIDERED TO BE RELEVANT | | | |
|--|--|--|---|
| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
| X | US 2017/084849 A1 (TSAI JUI-YI [US] ET AL) 23 March 2017 (2017-03-23) * paragraph [0097] * * column 82 - column 94 * ----- | 1-20 | INV. C07F15/00 C09K11/06 H01L51/00 |
| | | | TECHNICAL FIELDS SEARCHED (IPC) |
| | | | C07F C09K H01L |
| The present search report has been drawn up for all claims | | | |
| Place of search The Hague | | Date of completion of the search 26 August 2021 | Examiner Diederer, Jeroen |
| CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document | | | |

 1
EPO FORM 1503 03.82 (P04C01)

26-08-2021

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---------------------|----------------------------|---------------------|
| US 2017084849 | A1 | 23-03-2017 | NONE |
| ----- | | | |

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82