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

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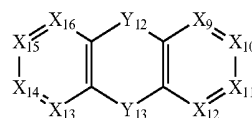
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(57) **ABSTRACT**

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A condensed cyclic compound and an organic light-emitting device including the same are provided. A condensed cyclic compound may be represented by Formula 1:

(21) Appl. No.: **15/714,652**



<Formula 1>

(22) Filed: **Sep. 25, 2017**

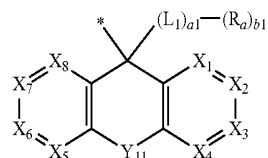
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wherein X_i may be C(R_i) or N or a substituent including Formula 2, wherein i is an integer:

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Publication Classification

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H01L 51/00 (2006.01)
H01L 51/50 (2006.01)
H01L 51/52 (2006.01)



<Formula 2>

(52) **U.S. Cl.**
CPC *H01L 51/0069* (2013.01); *H01L 51/5092* (2013.01); *H01L 51/5072* (2013.01); *H01L 51/506* (2013.01); *H01L 51/0071* (2013.01);

Further details about the structures of Formula 1 and Formula 2 are provided.

30

220
190
150
110

FIG. 1

10

190
150
110

FIG. 2

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190
150
110
210

FIG. 3

30

220
190
150
110

FIG. 4

40

220
190
150
110
210

**CONDENSED CYCLIC COMPOUND AND
ORGANIC LIGHT-EMITTING DEVICE
INCLUDING THE SAME**

CROSS-REFERENCE TO RELATED
APPLICATION

[0001] This application claims the benefit of Korean Patent Application No. 10-2016-0123384 filed on Sep. 26, 2016 in the Korean Intellectual Property Office, the disclosure of which is incorporated herein in its entirety by reference.

BACKGROUND

1. Field

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

2. Description of the Related Art

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

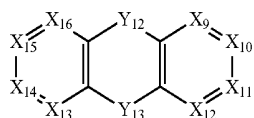
[0004] An example of such organic light-emitting devices may include a first electrode disposed on a substrate, and a hole transport region, an emission layer, an electron transport region, and a second electrode, which are sequentially disposed on the first electrode. Holes provided from the first electrode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

SUMMARY

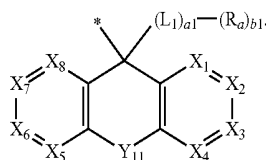
[0005] One or more exemplary embodiments of the present invention may include a condensed cyclic compound having a novel structure and an organic light-emitting device including the same.

[0006] Additional aspects will be set forth in part in the description which follows and, in part, will be apparent from the description, or may be learned by practice of the presented embodiments.

[0007] According to an exemplary embodiment of the present invention, a condensed cyclic compound is represented by Formula 1:



<Formula 1>



<Formula 2>

[0008] In Formulae 1 and 2,

[0009] X_1 is $C(R_1)$ or N , X_2 is $C(R_2)$ or N , X_3 is $C(R_3)$ or N , X_4 is $C(R_4)$ or N , X_5 is $C(R_5)$ or N , X_6 is $C(R_6)$ or N , X_7 is $C(R_7)$ or N , X_8 is $C(R_8)$ or N , X_9 is $C(R_9)$, N or C combined with a group represented by Formula 2, X_{10} is $C(R_{10})$, N , or C combined with a group represented by Formula 2, X_{11} is $C(R_{11})$, N , or C combined with a group represented by Formula 2, X_{12} is $C(R_{12})$, N , or C combined with a group represented by Formula 2, X_{13} is $C(R_{13})$ or N , X_{14} is $C(R_{14})$ or N , X_{15} is $C(R_{15})$ or N , X_{16} is $C(R_{16})$ or N , and at least one selected from X_9 to X_{12} is C combined with a group represented by Formula 2,

[0010] Y_{11} is selected from a single bond, a $C(R_{21})(R_{22})$, $Si(R_{21})(R_{22})$, O , S , $P(=O)(R_{21})$, $S(=O)$, $S(=O)_2$, and $N(R_{21})$,

[0011] Y_{12} is selected from a single bond, a $C(R_{23})(R_{24})$, $Si(R_{23})(R_{24})$, O , S , $P(=O)(R_{23})$, $S(=O)$, $S(=O)_2$, and $N(R_{23})$,

[0012] Y_{13} is selected from a single bond, a $C(R_{25})(R_{26})$, $Si(R_{25})(R_{26})$, O , S , $P(=O)(R_{25})$, $S(=O)$, $S(=O)_2$, and $N(R_{25})$,

[0013] L_1 is a substituted or unsubstituted C_3 - C_{60} carbocyclic group or a substituted or unsubstituted C_1 - C_{60} heterocyclic group,

[0014] a_1 is an integer of 1 to 3, wherein, when a_1 is 2 or greater, at least two $L_1(s)$ are the same as or different from each other,

[0015] R_a is selected from a cyano group, $-Si(Ar_1)(Ar_2)(Ar_3)$, $-S(=O)_2(Ar_1)$, and $-P(=O)(Ar_1)(Ar_2)$,

[0016] b_1 is an integer of 1 to 3, wherein, when b_1 is 2 or greater, at least two $R_a(s)$ are the same as or different from each other,

[0017] when R_a is $-Si(Ar_1)(Ar_2)(Ar_3)$, $-S(=O)_2(Ar_1)$, or $-P(=O)(Ar_1)(Ar_2)$, L_1 and Ar_1 are optionally linked to each other to form a ring,

[0018] Ar_1 and Ar_2 are optionally linked to each other to form a ring,

[0019] Ar_1 to Ar_3 are each independently selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1 - C_{60} alkyl group, a substituted or unsubstituted C_2 - C_{60} alkenyl group, a substituted or unsubstituted C_2 - C_{60} alkynyl group, a substituted or unsubstituted C_1 - C_{60} alkoxy group, a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6 - C_{60} aryl group, a substituted or unsubstituted C_6 - C_{60} aryloxy group, a substituted or unsubstituted C_6 - C_{60} arylthio group, a substituted or unsubstituted C_1 - C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group,

[0020] R_1 to R_{16} and R_{21} to R_{26} are each independently selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1 - C_{60} alkyl group, a substituted or unsubstituted C_2 - C_{60} alkenyl group, a substituted or unsubstituted C_2 - C_{60} alkynyl group, a substituted or unsubstituted C_1 - C_{60} alkoxy group, a substituted or unsubstituted C_3 - C_{10}

cycloalkyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(Q₁)(Q₂)(Q₃), —N(Q₁)(Q₂), —B(Q₁)(Q₂), —C(=O)(Q₁), —S(=O)₂(Q₁), and —P(=O)(Q₁)(Q₂).

[0021] at least one substituent of the substituted C₃-C₆₀ carbocyclic group, the substituted C₁-C₆₀ heterocyclic group, the substituted C₁-C₆₀ alkyl group, the substituted C₂-C₆₀ alkenyl group, the substituted C₂-C₆₀ alkynyl group, the substituted C₁-C₆₀ alkoxy group, the substituted C₃-C₁₀ cycloalkyl group, the substituted C₁-C₁₀ heterocycloalkyl group, the substituted C₃-C₁₀ cycloalkenyl group, the substituted C₁-C₁₀ heterocycloalkenyl group, the substituted C₆-C₆₀ aryl group, the substituted C₆-C₆₀ aryloxy group, the substituted C₆-C₆₀ arylthio group, the substituted C₁-C₆₀ heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group is selected from:

[0022] deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino 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;

[0023] 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 amino group, an amidino group, a hydrazino group, a hydrazono group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —Si(Q₁₁)(Q₁₂)(Q₁₃), —N(Q₁₁)(Q₁₂), —B(Q₁₁)(Q₁₂), —C(=O)(Q₁₁), —S(=O)₂(Q₁₁), and —P(=O)(Q₁₁)(Q₁₂);

[0024] a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group;

[0025] a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a 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 biphenyl group, a terphenyl group, —Si(Q₂₁)(Q₂₂)(Q₂₃), —N(Q₂₁)(Q₂₂), B(Q₂₁)(Q₂₂), —C(=O)(Q₂₁), —S(=O)₂(Q₂₁), and —P(=O)(Q₂₁)(Q₂₂); and

[0026] —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂), and

[0027] 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 amino 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, and indicates a binding site to a neighboring atom.

[0028] According to an exemplary embodiment of the present invention, an organic light-emitting device includes a first electrode; a second electrode facing the first electrode; an organic layer disposed between the first electrode and the second electrode. The organic layer includes an emission layer. The organic layer includes at least one of the condensed cyclic compounds represented by Formula 1.

BRIEF DESCRIPTION OF THE DRAWINGS

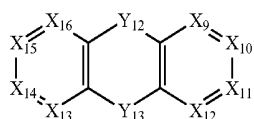
[0029] These and/or other aspects will become apparent and more readily appreciated from the following description of the embodiments, taken in conjunction with the accompanying drawings in which:

[0030] Each of FIGS. 1, 2, 3, and 4 is a schematic cross-sectional diagram illustrating an organic light-emitting device according to an exemplary embodiment of the present disclosure.

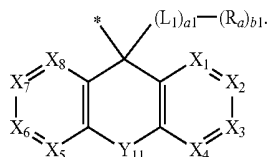
DETAILED DESCRIPTION

[0031] Reference will now be made in detail to embodiments, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout. In this regard, the present embodiments may have different forms and should not be construed as being limited to the descriptions set forth herein. Accordingly, the embodiments are merely described below, by referring to the figures, to explain aspects 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. Expressions such as “at least one of” when preceding a list of elements, modify the entire list of elements and do not modify the individual elements of the list.

[0032] According to an aspect of embodiments, a condensed cyclic compound may be represented by Formula 1:



<Formula 1>



<Formula 2>

[0033] In Formulae 1 and 2,

[0034] X_1 may be $C(R_1)$ or N, X_2 may be $C(R_2)$ or N, X_3 may be $C(R_3)$ or N, X_4 may be $C(R_4)$ or N, X_5 may be $C(R_5)$ or N, X_6 may be $C(R_6)$ or N, X_7 may be $C(R_7)$ or N, X_8 may be $C(R_8)$ or N, X_9 may be $C(R_9)$, N, or C combined with a group represented by Formula 2, X_{10} may be $C(R_{10})$, N, or C combined with a group represented by Formula 2, X_{11} may be $C(R_{11})$, N, or C combined with a group represented by Formula 2, X_{12} may be $C(R_{12})$, N, or C combined with a group represented by Formula 2, X_{13} may be $C(R_{13})$ or N, X_{14} may be $C(R_{14})$ or N, X_{15} may be $C(R_{15})$ or N, X_{16} may be $C(R_{16})$ or N, and at least one selected from X_9 to X_{12} may be C combined with a group represented by Formula 2, and indicates a binding site to a neighboring atom.

[0035] In Formulae 1 and 2, R_1 to R_{16} may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1 - C_{60} alkyl group, a substituted or unsubstituted C_2 - C_{60} alkenyl group, a substituted or unsubstituted C_2 - C_{60} alkynyl group, a substituted or unsubstituted C_1 - C_{60} alkoxy group, a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6 - C_{60} aryl group, a substituted or unsubstituted C_6 - C_{60} aryloxy group, a substituted or unsubstituted C_6 - C_{60} arylthio group, a substituted or unsubstituted C_1 - C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(Q_1)(Q_2)(Q_3), —N(Q_1)(Q_2), —B(Q_1)(Q_2), —C(=O)(Q_1), —S(=O)₂(Q_1), and —P(=O)(Q_1)(Q_2).

[0036] In an exemplary embodiment, R_1 to R_{16} in Formulae 1 and 2 may each independently be selected from:

[0037] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

[0038] a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, and a nitro group;

[0039] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyridinyl group, a pyrimidinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

[0040] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyridinyl group, a pyrimidinyl 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 C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, —N(Q_{31})(Q_{32}) and —Si(Q_{31})(Q_{32})(Q_{33}); and

[0041] —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

[0042] Q_1 to Q_3 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.

[0043] In an exemplary embodiment, R_1 to R_{16} in Formulae 1 and 2 may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group, but the exemplary embodiments are not limited thereto.

[0044] In an exemplary embodiment, R_1 to R_{16} in Formulae 1 and 2 may each independently be hydrogen, deuterium, or a cyano group, but the embodiments are not limited thereto.

[0045] In an exemplary embodiment, in Formulae 1 and 2,

[0046] Y_{11} may be selected from a single bond, a $C(R_{21})$ (R_{22}), Si(R_{21})(R_{22}), O, S, P(=O)(R_{21}), S(=O), S(=O)₂, and N(R_{21}),

[0047] Y_{12} may be selected from a single bond, a $C(R_{23})$ (R_{24}), Si(R_{23})(R_{24}), O, S, P(=O)(R_{23}), S(=O), S(=O)₂, and N(R_{23}), and

[0048] Y_{13} may be selected from a single bond, a $C(R_{25})$ (R_{26}), Si(R_{25})(R_{26}), O, S, P(=O)(R_{25}), S(=O), S(=O)₂, and N(R_{25}).

[0049] In an exemplary embodiment, R_{21} to R_{26} in Formulae 1 and 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 substituted or unsubstituted C_1 - C_{60} alkyl group, a substituted or unsubstituted C_2 - C_{60} alkenyl group, a substituted or unsubstituted C_2 - C_{60} alkynyl group, a substituted or unsubstituted C_1 - C_{60} alkoxy group, a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6 - C_{60} aryl group, a substituted or unsubstituted C_6 - C_{60} aryloxy group, a substituted or unsubstituted C_6 - C_{60} arylthio group, a substituted or unsubstituted C_1 - C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(Q_1)(Q_2)(Q_3), —N(Q_1)(Q_2), —B(Q_1)(Q_2), —C(=O)(Q_1), —S(=O)₂(Q_1), and —P(=O)(Q_1)(Q_2).

[0050] In an exemplary embodiment, R_{21} to R_{26} in Formulae 1 and 2 each independently be selected from:

[0051] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

[0052] a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, and a nitro group;

[0053] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyridinyl group, a pyrimidinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

[0054] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyridinyl group, a pyrimidinyl 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 C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, —N(Q₃₁)(Q₃₂), and —Si(Q₃₁)(Q₃₂)(Q₃₃); and

[0055] —Si(Q₁)(Q₂)(Q₃), —N(Q₁)(Q₂), B(Q₁)(Q₂), —C(=O)(Q₁), —S(=O)₂(Q₁), and —P(=O)(Q₁)(Q₂), and

[0056] Q₁ to Q₃ and Q₃₁ to Q₃₃ 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, but the embodiments are not limited thereto.

[0057] In an exemplary embodiment, R₂₁ to R₂₆ in Formulae 1 and 2 may each independently be selected from:

[0058] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

[0059] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group;

[0060] a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, and a nitro group, but the embodiments are not limited thereto.

[0061] In an exemplary embodiment, R₂₁ to R₂₆ in Formulae 1 and 2 may each independently be selected from:

[0062] a methyl group, an ethyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and a pyridinyl group; and

[0063] a phenyl group substituted with a cyano group, but the embodiments are not limited thereto.

[0064] In Formula 2, L₁ may be a substituted or unsubstituted C₃-C₆₀ carbocyclic group or a substituted or unsubstituted C₁-C₆₀ heterocyclic group.

[0065] In an exemplary embodiment, L₁ in Formula 2 may be selected from:

[0066] a benzene group, a pentalene group, an indene group, a naphthalene group, an azulene group, a heptalene group, an indacene group, an acenaphthalene group, a fluorene group, a spiro-bifluorene group, a spiro-benzofluorene 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 pyrrole group, a thiophene group, a furan group, a silole 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, a triazine group, a benzofuran group, a benzothiophene group, a benzosilole group, a dibenzofuran group, a dibenzothiophene group, a dibenzosilole group, a carbazole group, a benzocarbazole group, a dibenzocarbazole group, a benzimidazole group, and an imidazopyridine group; and

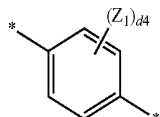
[0067] a benzene group, a pentalene group, an indene group, a naphthalene group, an azulene group, a heptalene group, an indacene group, an acenaphthalene group, a fluorene group, a spiro-bifluorene group, a spiro-benzofluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, 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 pyrrole group, a thiophene group, a furan group, a silole 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, a triazine group, a benzofuran group, a benzothiophene group, a benzosilole group, a dibenzofuran group, a dibenzothiophene group, a dibenzosilole group, a carbazole group, a benzocarbazole group, a dibenzocarbazole group, a benzimidazole group, and an imidazopyridine group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano 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 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 pyrrolyl group, a thiophenyl group, a furanyl group, a carbazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂);

[0068] Q₃₁ to Q₃₃ may each independently be selected from a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and a pyridinyl group, and

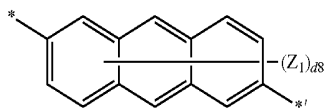
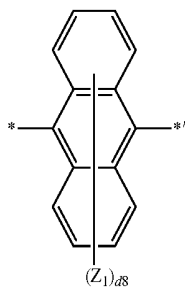
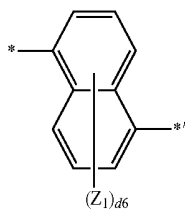
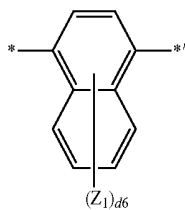
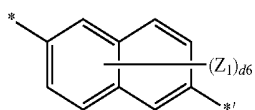
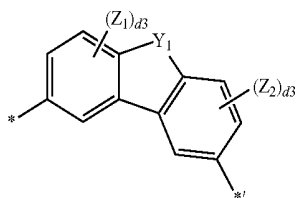
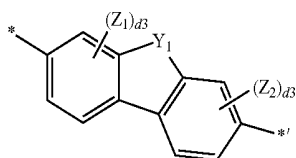
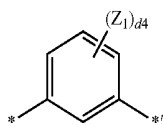
[0069] * and *' each indicate a binding site to a neighboring atom.

[0070] In an exemplary embodiment, L₁ in Formula 2 may be selected from groups represented by Formulae 3-1 to 3-49, but the embodiments are not limited thereto:

Formula 3-1

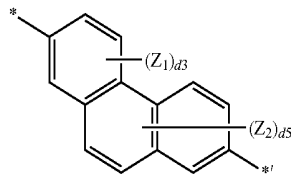


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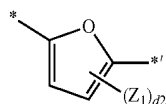


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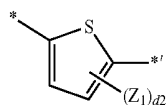
Formula 3-2



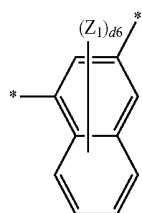
Formula 3-3



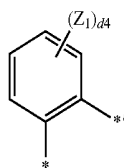
Formula 3-4



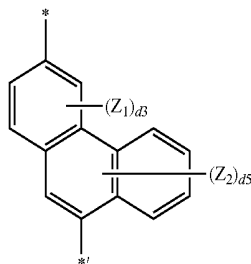
Formula 3-5



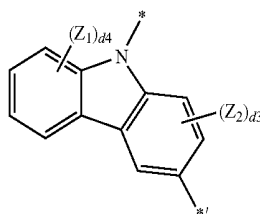
Formula 3-6



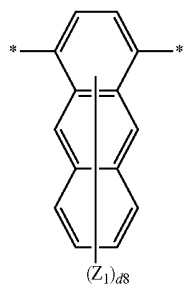
Formula 3-7



Formula 3-8



Formula 3-9



Formula 3-10

Formula 3-11

Formula 3-12

Formula 3-13

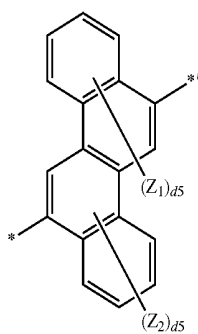
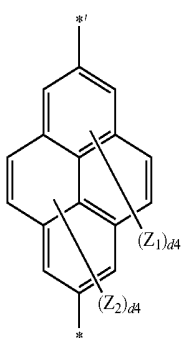
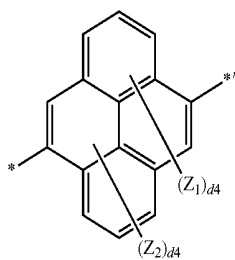
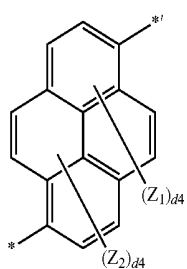
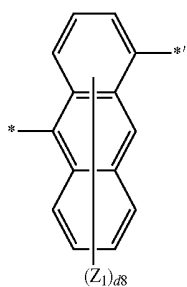
Formula 3-14

Formula 3-15

Formula 3-16

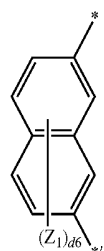
Formula 3-17

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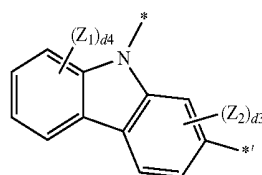
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Formula 3-18



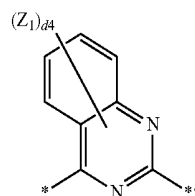
Formula 3-23

Formula 3-19



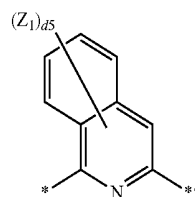
Formula 3-24

Formula 3-20



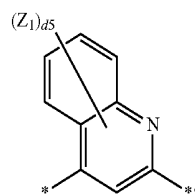
Formula 3-25

Formula 3-21

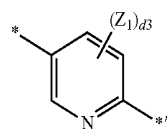


Formula 3-26

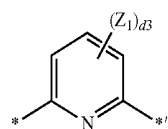
Formula 3-22



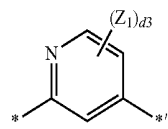
Formula 3-27



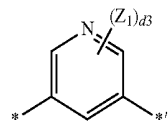
Formula 3-28



Formula 3-29

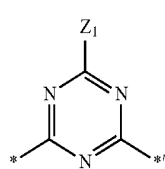
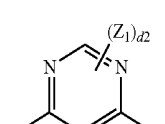
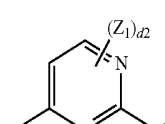
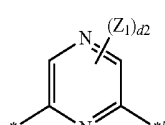
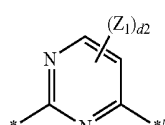
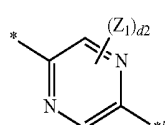
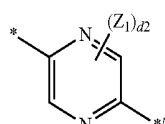
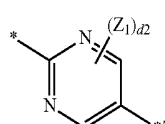
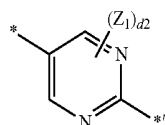
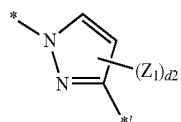
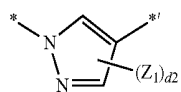


Formula 3-30



Formula 3-31

-continued



Formula 3-32

Formula 3-33

Formula 3-34

Formula 3-35

Formula 3-36

Formula 3-37

Formula 3-38

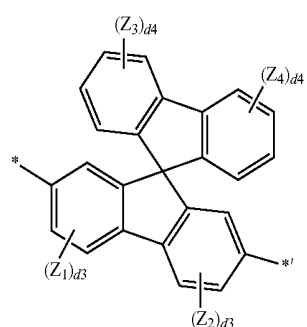
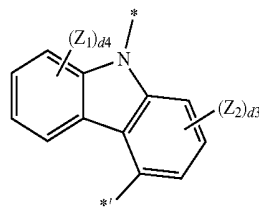
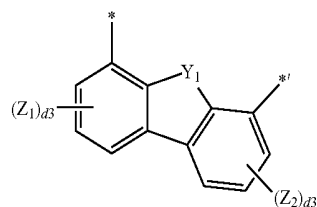
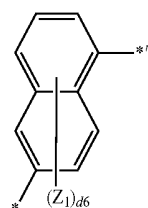
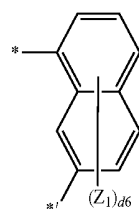
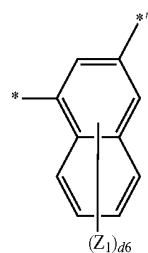
Formula 3-39

Formula 3-40

Formula 3-41

Formula 3-42

-continued



Formula 3-43

Formula 3-44

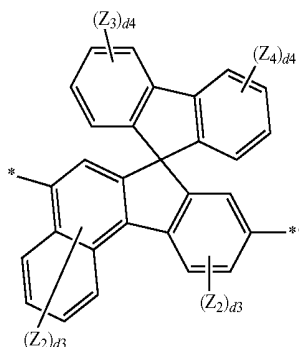
Formula 3-45

Formula 3-46

Formula 3-47

Formula 3-48

-continued



Formula 3-49

[0071] In Formulae 3-1 to 3-49,

[0072] Y_1 may be O, S, $C(Z_5)(Z_6)$, $N(Z_5)$, or $Si(Z_5)(Z_6)$,

[0073] Z_1 to Z_6 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} alkenyl group, a C_1 - C_{20} alkynyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, $-Si(Q_{31})(Q_{32})(Q_{33})$, $-N(Q_{31})(Q_{32})$, $-B(Q_{31})(Q_{32})$, $-C(=O)(Q_{31})$, $-S(=O)_2(Q_{31})$, and $-P(=O)(Q_{31})(Q_{32})$,

[0074] 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,

[0075] d_2 may be 1 or 2,

[0076] d_3 may be an integer of 1 to 3,

[0077] d_4 may be an integer of 1 to 4,

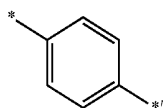
[0078] d_5 may be an integer of 1 to 5,

[0079] d_6 may be an integer of 1 to 6,

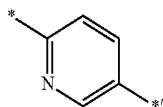
[0080] d_8 may be an integer of 1 to 8, and

[0081] * and *' each indicate a binding site to a neighboring atom.

[0082] In an exemplary embodiment, L_1 in Formula 2 may be selected from groups represented by Formulae 4-1 to 4-39, but the embodiments are not limited thereto:

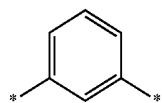


Formula 4-1

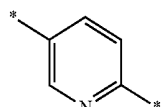


Formula 4-2

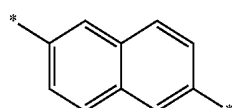
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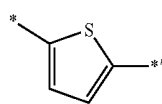
Formula 4-3



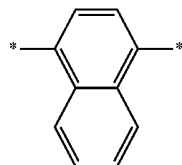
Formula 4-4



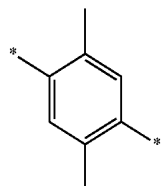
Formula 4-5



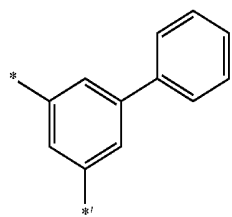
Formula 4-6



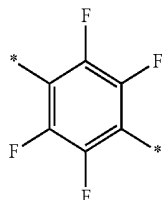
Formula 4-7



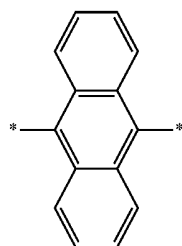
Formula 4-8



Formula 4-9

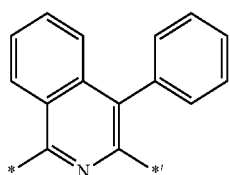
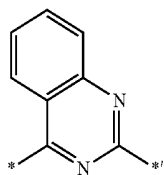
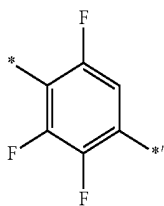
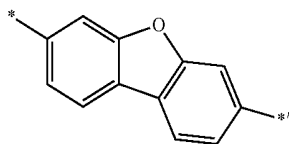
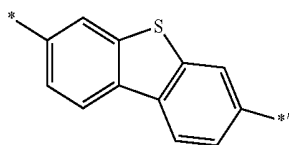
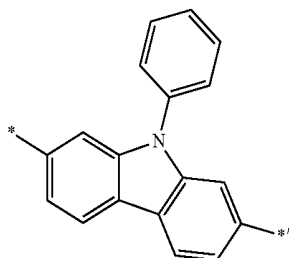
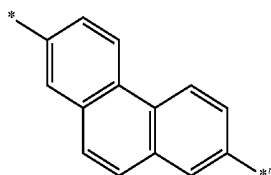
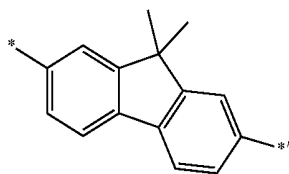


Formula 4-10



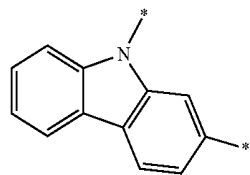
Formula 4-11

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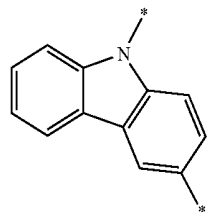


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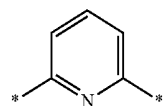
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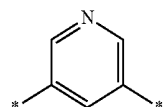
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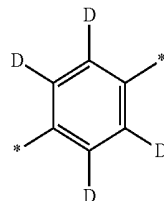
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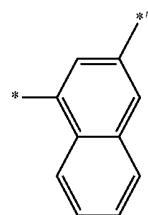
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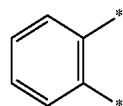
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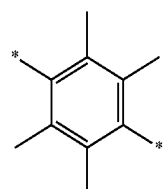
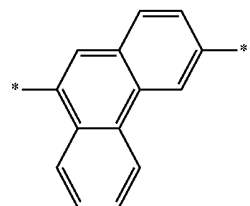
Formula 4-17



Formula 4-18



Formula 4-19



Formula 4-20

Formula 4-21

Formula 4-22

Formula 4-23

Formula 4-24

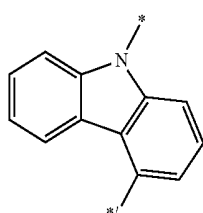
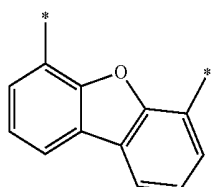
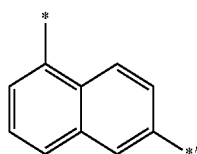
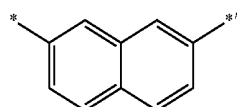
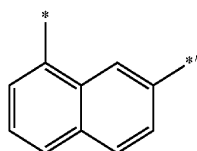
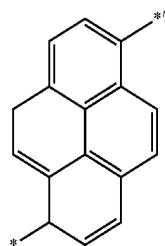
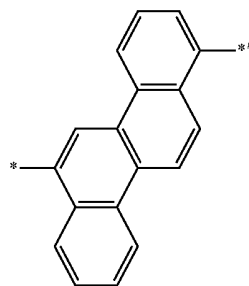
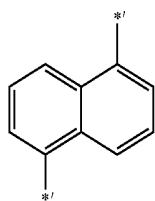
Formula 4-25

Formula 4-26

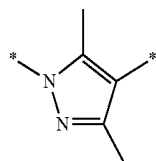
Formula 4-27

Formula 4-28

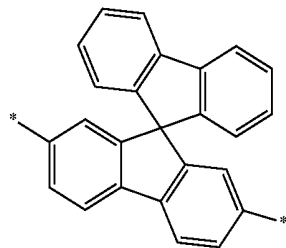
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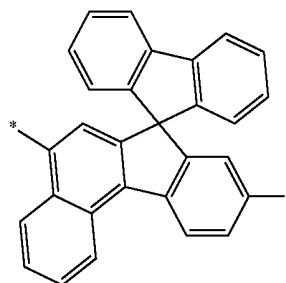
Formula 4-29



Formula 4-30



Formula 4-31



Formula 4-32

[0083] * and *' in Formulae 4-1 to 4-39 each indicate a binding site to a neighboring atom.

[0084] For example, L_1 in Formula 2 may be selected from a benzene group, a pyridine group, and a pyrimidine group, but the embodiments are not limited thereto.

[0085] In Formula 2,

Formula 4-33

[0086] a_1 may be an integer of 1 to 3. a_1 may indicate the number of L_1 . When a_1 is 2 or greater, at least two L_1 (s) may be the same as or different from each other. In an exemplary embodiment, a_1 may be 1, but the embodiments are not limited thereto.

Formula 4-34

[0087] In Formula 2, R_a may be selected from a cyano group, $-\text{Si}(\text{Ar}_1)(\text{Ar}_2)(\text{Ar}_3)$, $-\text{S}(=\text{O})_2(\text{Ar}_1)$, and $-\text{P}(=\text{O})(\text{Ar}_1)(\text{Ar}_2)$.

Formula 4-35

[0088] In an exemplary embodiment, when R_a in Formula 2 is $-\text{Si}(\text{Ar}_1)(\text{Ar}_2)(\text{Ar}_3)$, $-\text{S}(=\text{O})_2(\text{Ar}_1)$, or $-\text{P}(=\text{O})(\text{Ar}_1)(\text{Ar}_2)$, L_1 and Ar_1 may optionally be linked to each other to form a ring.

Formula 4-36

[0089] In an exemplary embodiment, Ar_1 and Ar_2 in Formula 2 may optionally be linked to each other to form a ring.

[0090] In Formula 2, Ar_1 to Ar_3 may each independently be selected from hydrogen, deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1 - C_{60} alkyl group, a substituted or unsubstituted C_2 - C_{60} alkenyl group, a substituted or unsubstituted C_2 - C_{60} alkynyl group, a substituted or unsubstituted C_1 - C_{60} alkoxy group, a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6 - C_{60} aryl group, a substituted or unsubstituted C_6 - C_{60} aryloxy group, a substituted or unsubstituted C_1 - C_{60} arylthio group, a substituted or unsubstituted C_1 - C_{60} het-

-continued

Formula 4-37

Formula 4-38

Formula 4-39

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

[0091] In an exemplary embodiment, Ar₁ to Ar₃ in Formula 2 may each independently be selected from:

[0092] 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 pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a thiophenyl group, a furanyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzonaphthofuranyl group, a dinaphthofuranyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a benzonaphtosilolyl group, a dinaphtosilolyl group, a benzimidazolyl group, a benzoimidazonaphthoimidazolyl group, and an imidazopyridinyl group; and

[0093] 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 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 pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a thiophenyl group, a furanyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzonaphthofuranyl group, a dinaphthofuranyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a benzonaphtosilolyl group, a dinaphtosilolyl group, a benzimidazolyl group, a benzoimidazonaphthoimidazolyl group, and an imidazopyridinyl 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 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 pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a

thiophenyl group, a furanyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group and —Si(Q₃₁)(Q₃₂)(Q₃₃), and

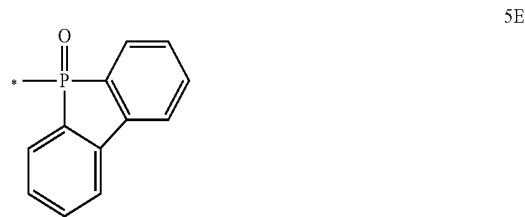
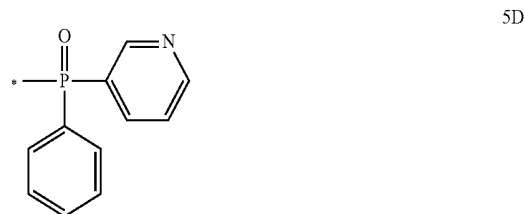
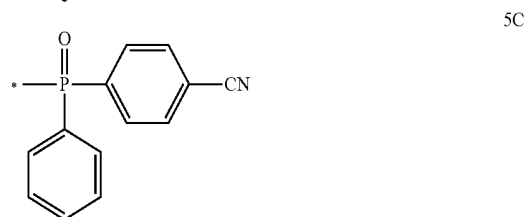
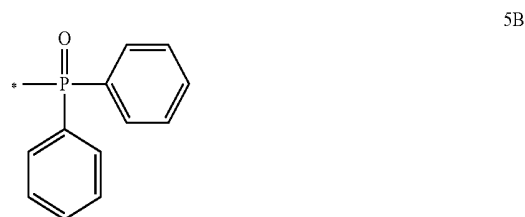
[0094] Q₃₁ to Q₃₃ may each independently be selected from a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0095] In an exemplary embodiment, Ar₁ to Ar₃ in Formula 2 may each independently be selected from:

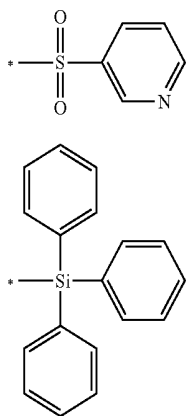
[0096] a phenyl group, a biphenyl group, a terphenyl group, a pyridinyl group, and a pyrimidinyl group; and

[0097] a phenyl group, a biphenyl group, a terphenyl group, a pyridinyl group, and a pyrimidinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, and a nitro group, but the embodiments are not limited thereto.

[0098] R_a in Formula 2 may be selected from groups represented by Formulae 5A to 5H, but the embodiments are not limited thereto:



-continued



[0099] * in Formulae 5A to 5H indicates a binding site to a neighboring atom.

[0100] b_1 in Formula 2 may be an integer of 1 to 3. b_1 in Formula 2 may indicate the number of R_a . When b_1 is 2 or greater, at least two $R_a(s)$ may be the same as or different from each other. In an exemplary embodiment, b_1 in Formula 2 may be 1 or 2.

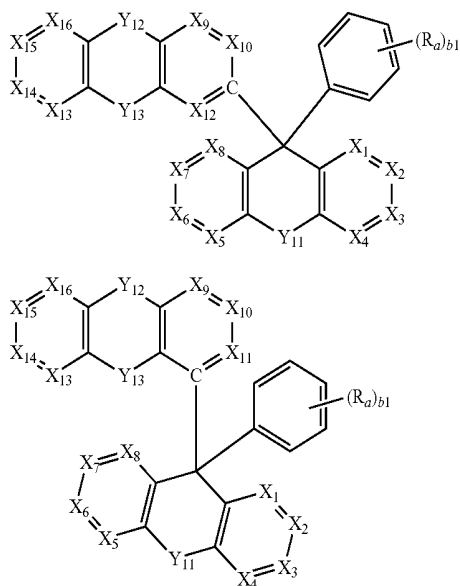
[0101] In an exemplary embodiment, in Formulae 1 and 2, R_1 to R_{16} may each independently be selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group, and

[0102] R_{21} to R_{26} may each independently be selected from:

[0103] a methyl group, an ethyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and a pyridinyl group; and

[0104] a phenyl group substituted with a cyano group.

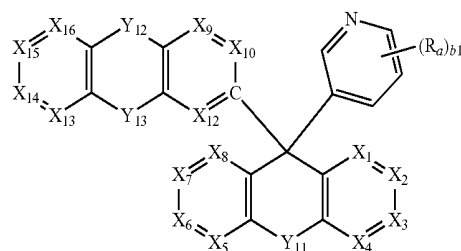
[0105] In exemplary embodiment, the condensed cyclic compound represented by Formula 1 may be represented by one selected from Formulae 1A to 1H:



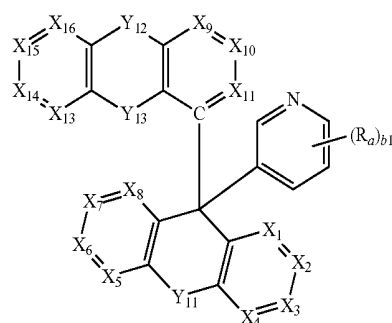
5G

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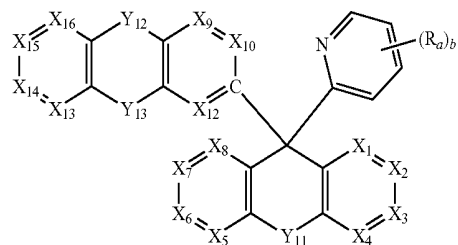
5H



1C

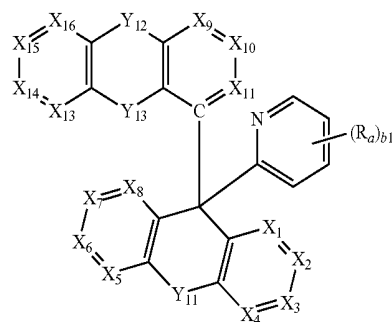


1D



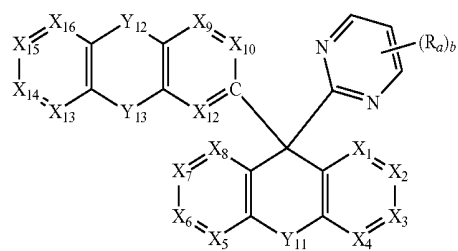
1E

1A



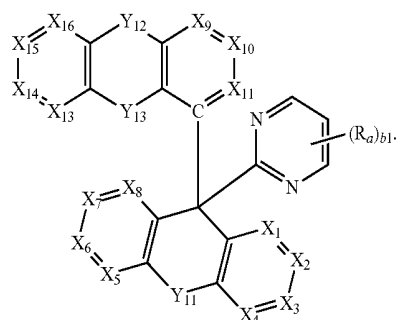
1F

1B



1G

-continued



[0106] In Formulae 1A to 1H, X_1 to X_{16} , Y_{11} to Y_{13} , R_a , and b_1 may each independently be the same as defined herein.

[0107] In Formulae 1A to 1H,

[0108] X_1 may be $C(R_1)$ or N, X_2 may be $C(R_2)$ or N, X_3 may be $C(R_3)$ or N, X_4 may be $C(R_4)$ or N, X_5 may be $C(R_5)$ or N, X_6 may be $C(R_6)$ or N, X_7 may be $C(R_7)$ or N, X_8 may be $C(R_8)$ or N, X_9 may be $C(R_9)$ or N, X_{10} may be $C(R_{10})$ or N, X_{11} may be $C(R_{11})$ or N, X_{12} may be $C(R_{12})$ or N, X_{13} may be $C(R_{13})$ or N, X_{14} may be $C(R_{14})$ or N, X_{15} may be $C(R_{15})$ or N, and X_{16} may be $C(R_{16})$ or N,

[0109] R_1 to R_{16} may each independently be hydrogen or a cyano group,

[0110] Y_{11} may be selected from a single bond, a $C(R_{21})$ (R_{22}), $Si(R_{21})(R_{22})$, O, S, $P(=O)(R_{21})$, $S(=O)$, $S(=O)_2$, and $N(R_{21})$,

[0111] Y_{12} may be selected from a single bond, a $C(R_{23})$ (R_{24}), $Si(R_{23})(R_{24})$, O, S, $P(=O)(R_{23})$, $S(=O)$, $S(=O)_2$, and $N(R_{23})$,

[0112] Y_{13} may be selected from a single bond, a $C(R_{25})$ (R_{26}), $Si(R_{25})(R_{26})$, O, S, $P(=O)(R_{25})$, $S(=O)$, $S(=O)_2$, and $N(R_{25})$,

[0113] R_{21} to R_{26} may each independently be selected from:

[0114] a methyl group, a phenyl group and a pyridinyl group; and

[0115] a phenyl group substituted with a cyano group,

[0116] R_a may be selected from a cyano group, $-Si(Ar_1)(Ar_2)(Ar_3)$, $-S(=O)_2(Ar_1)$, and $-P(=O)(Ar_1)(Ar_2)$,

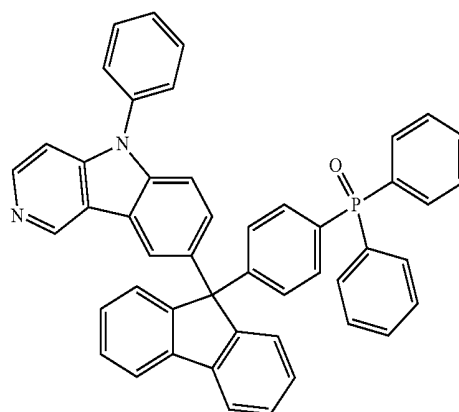
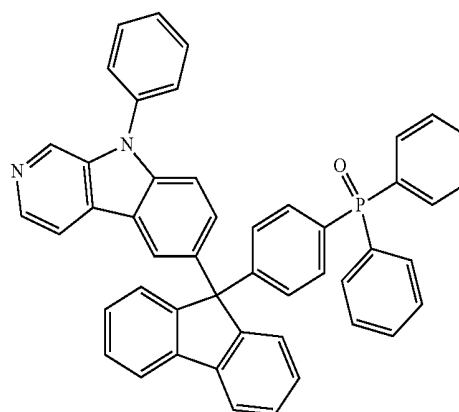
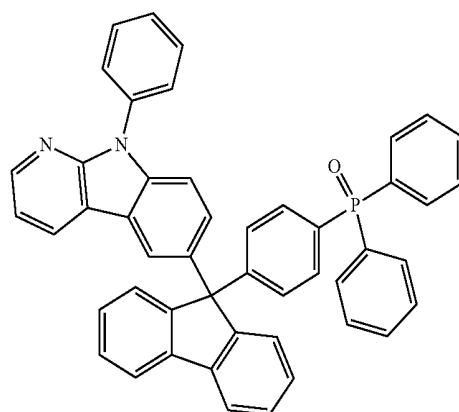
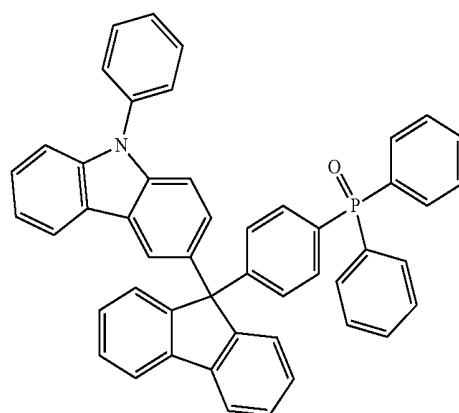
[0117] Ar_1 to Ar_3 may each independently be selected from:

[0118] a phenyl group and a pyridinyl group; and

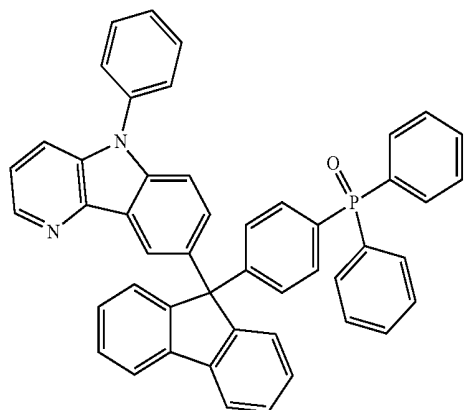
[0119] a phenyl group substituted with a cyano group, and

[0120] b_1 may be 1 or 2, but the embodiments are not limited thereto.

[0121] The condensed cyclic compound represented by Formula 1 may be one selected from groups represented by Formulae 1 to 80, but the embodiments are not limited thereto:

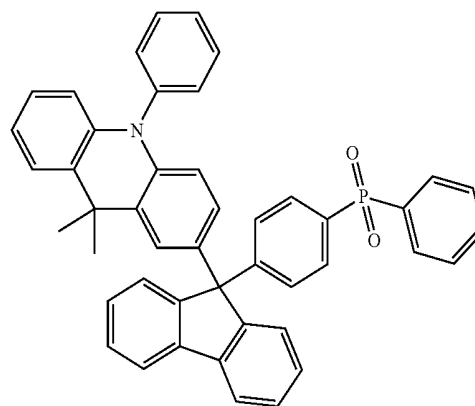


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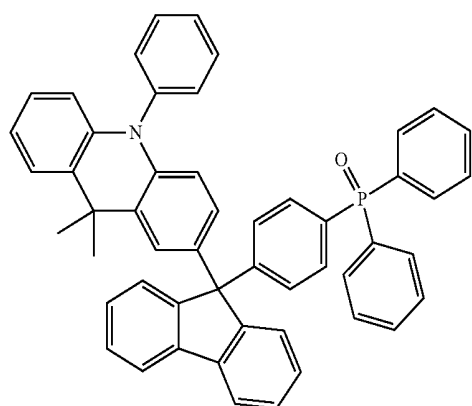


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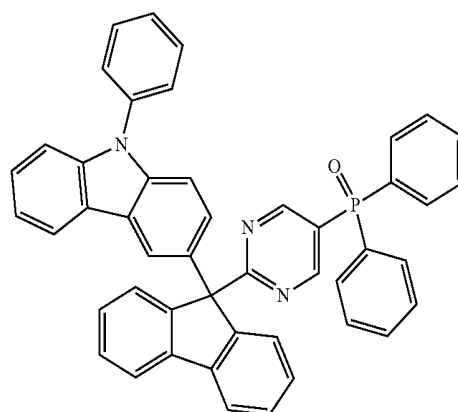
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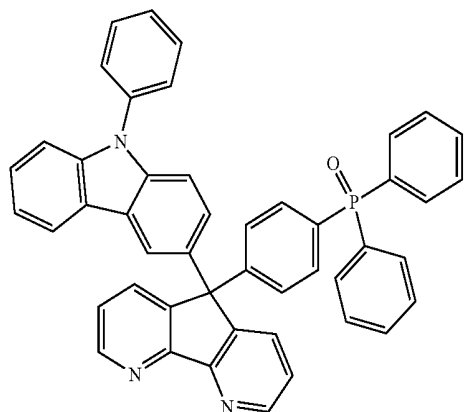
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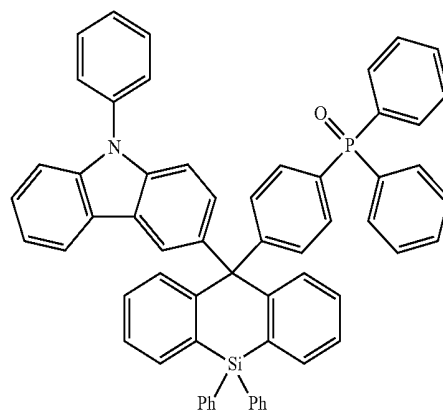
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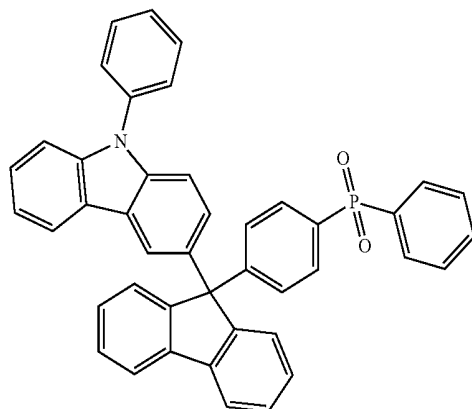
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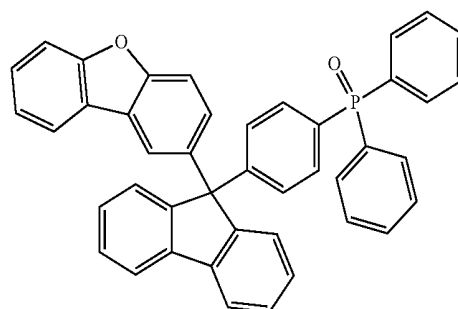
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11

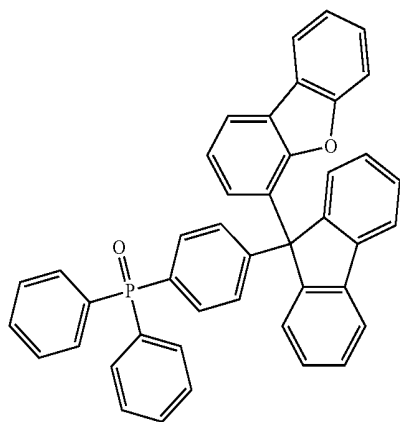


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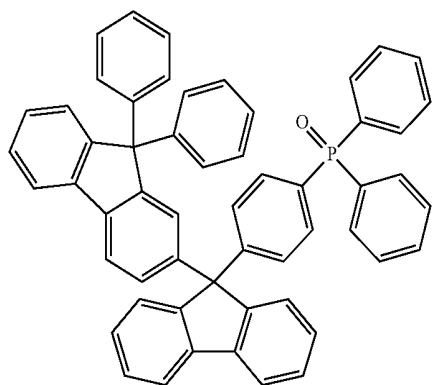


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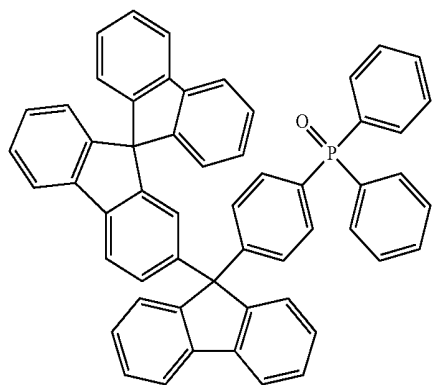
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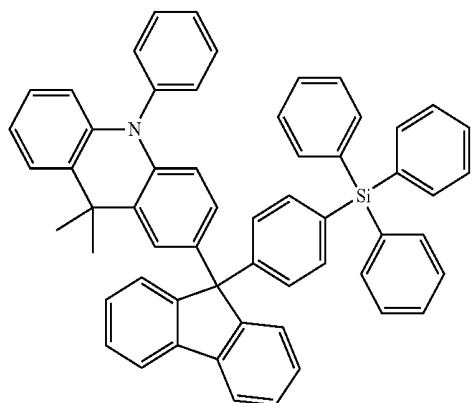
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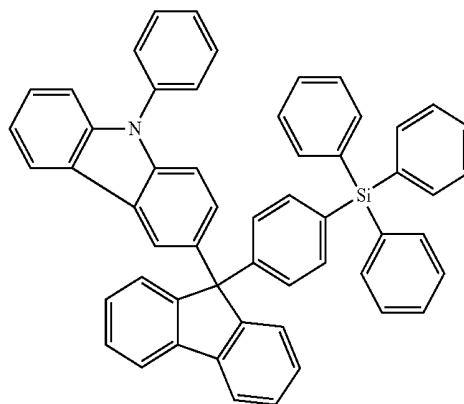


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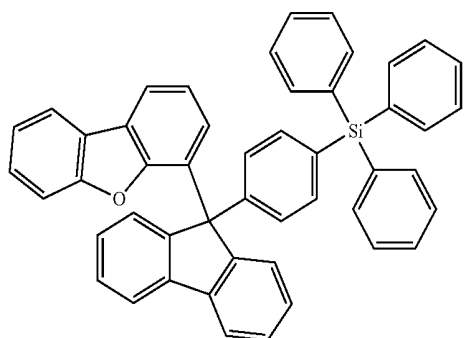


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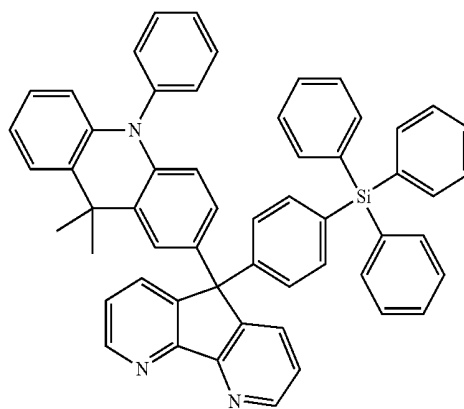
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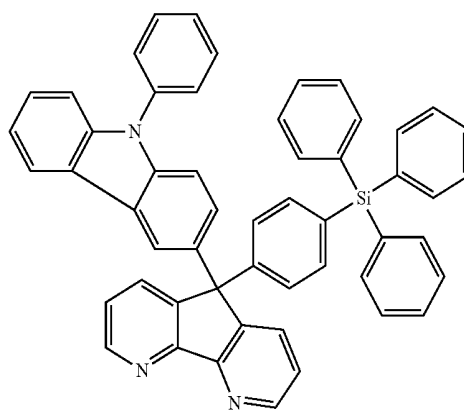
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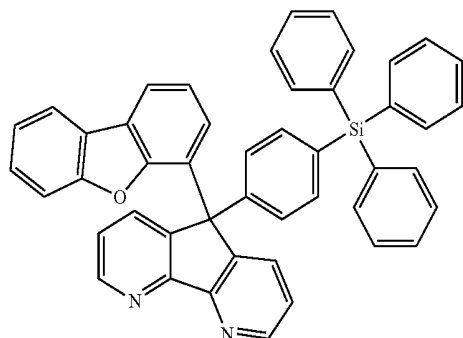


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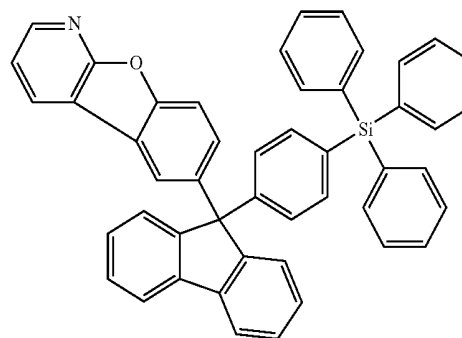
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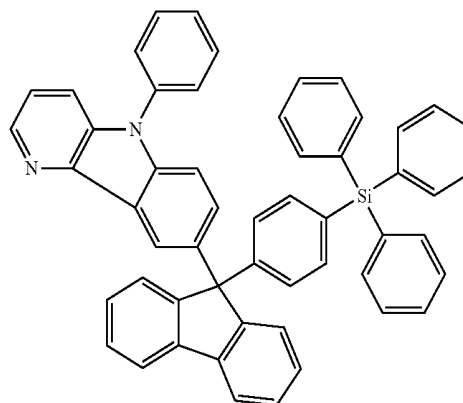
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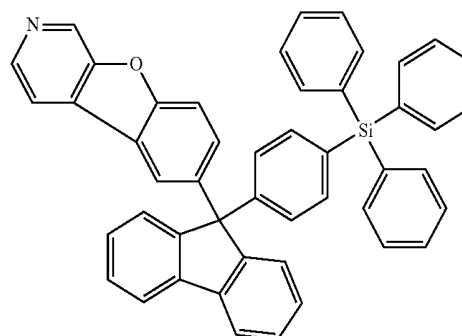


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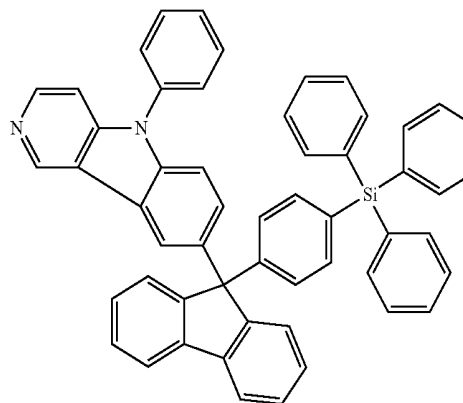
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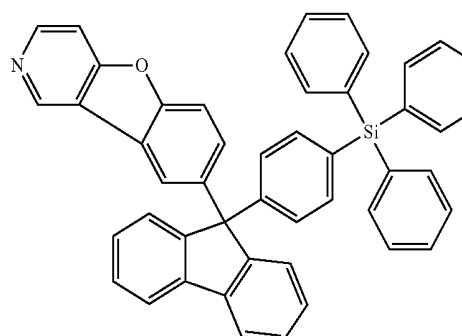
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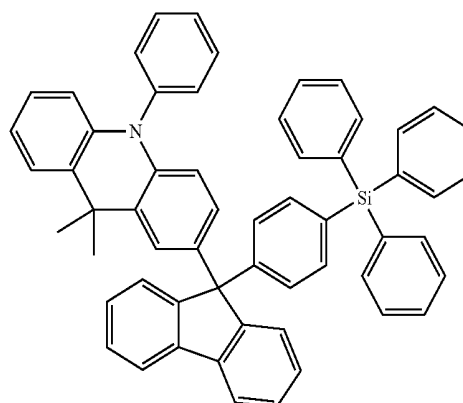
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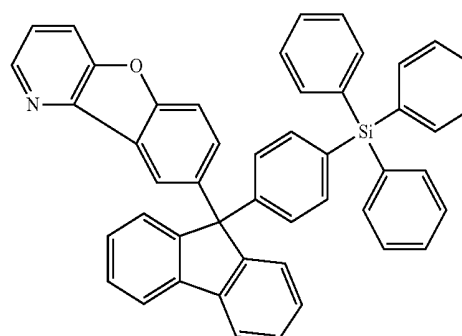
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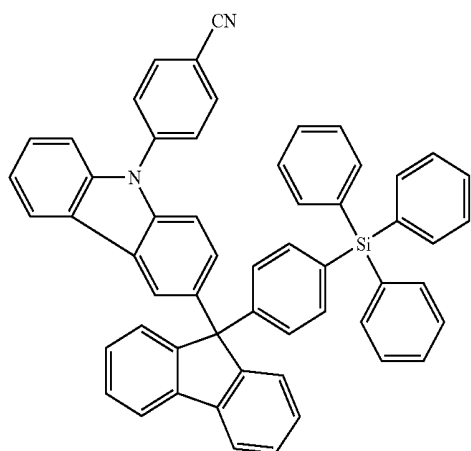
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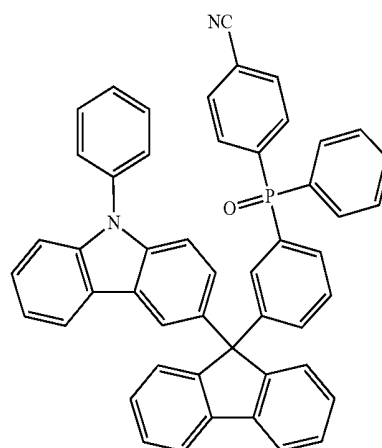
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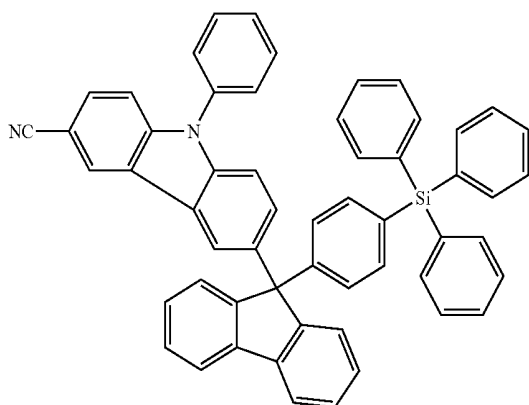
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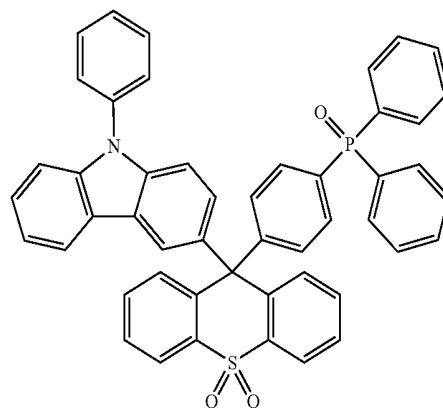
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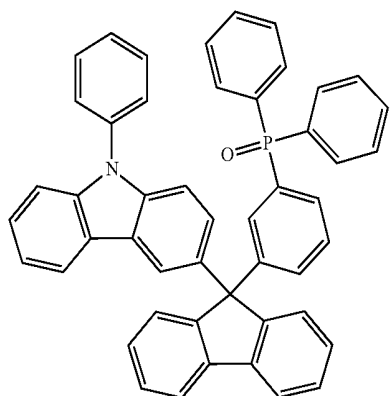


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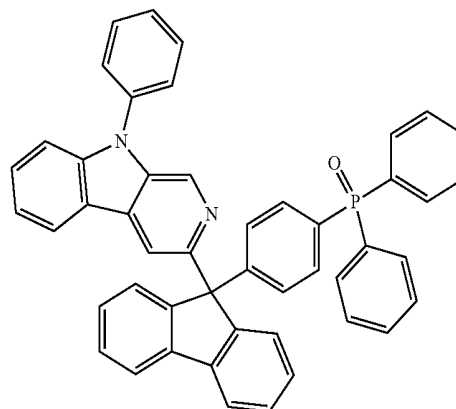


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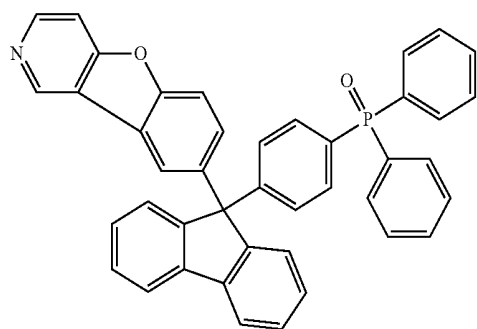
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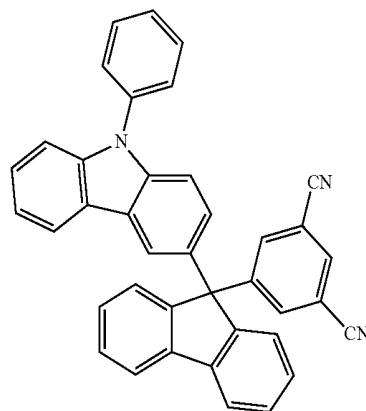
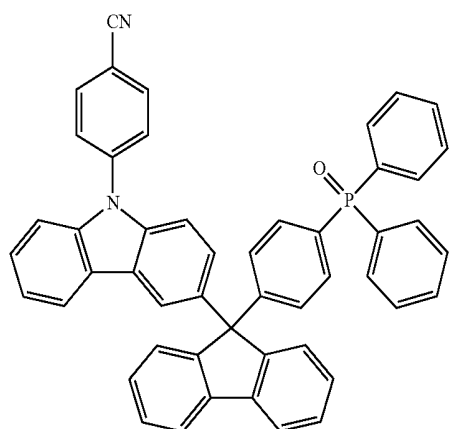
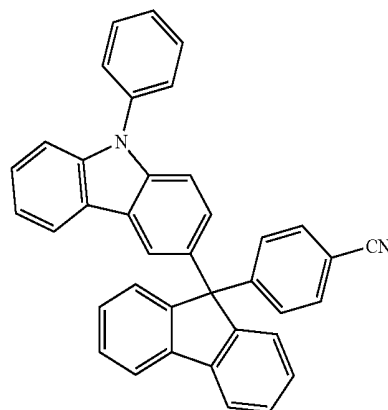
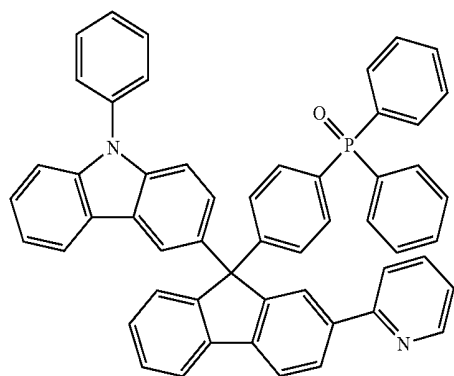
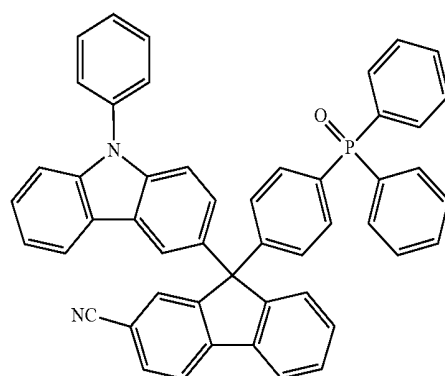
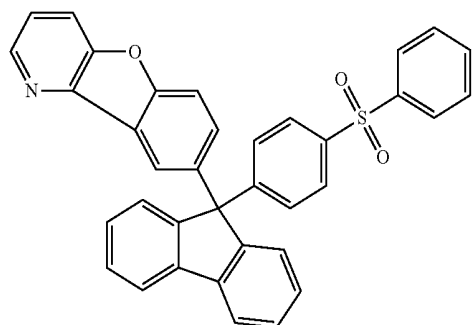
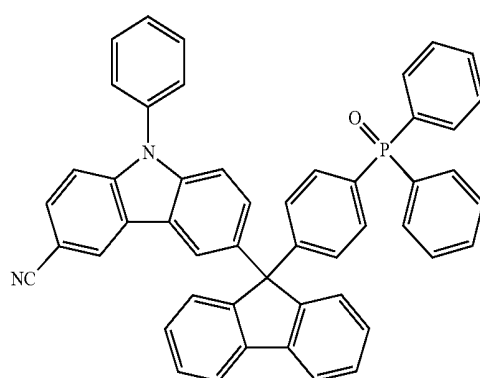
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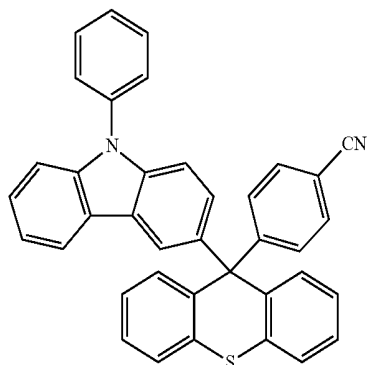
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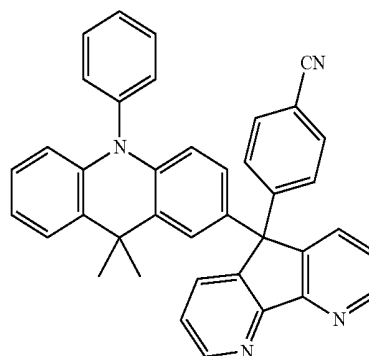


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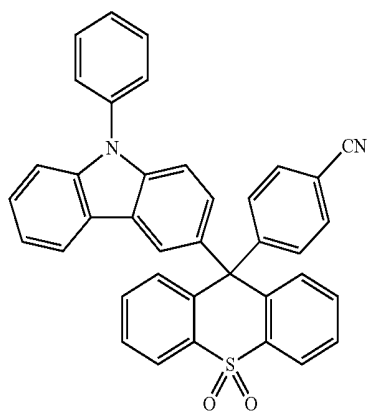


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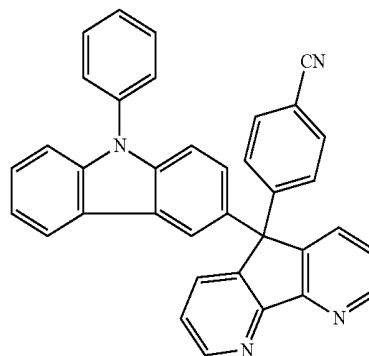
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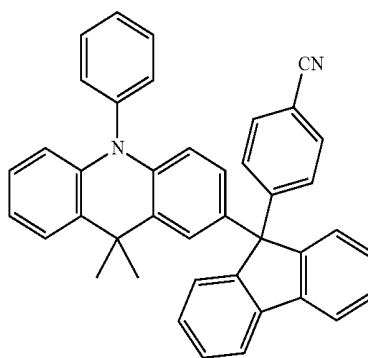
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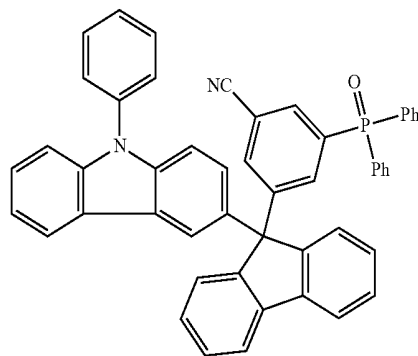
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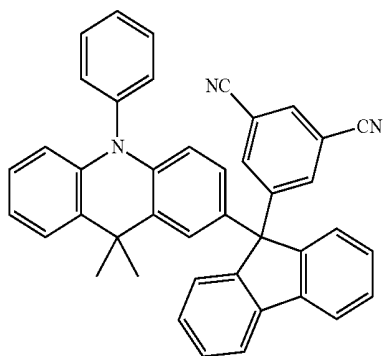
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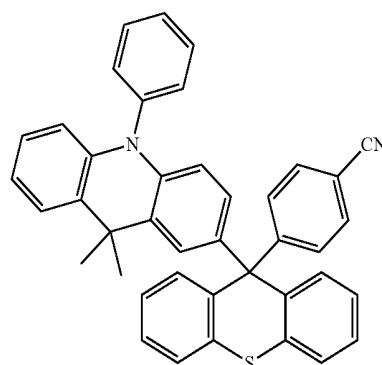
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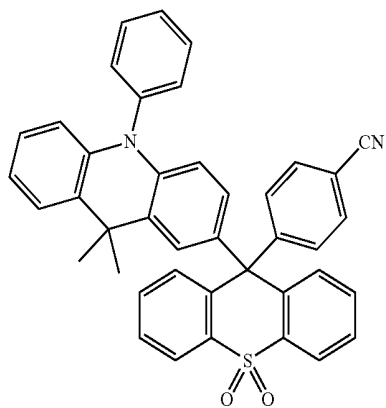


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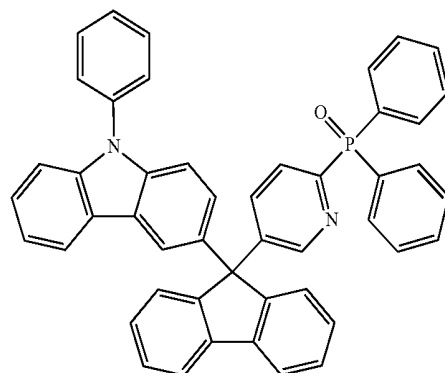
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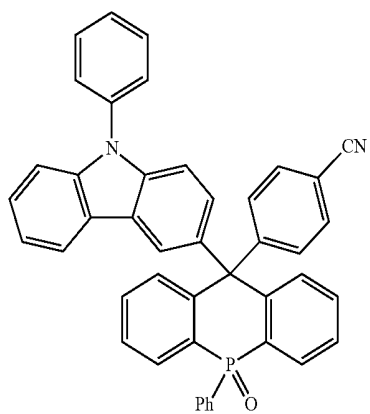


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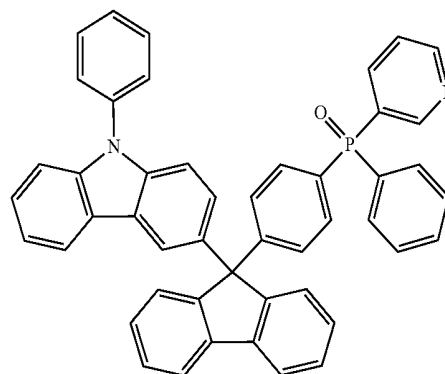
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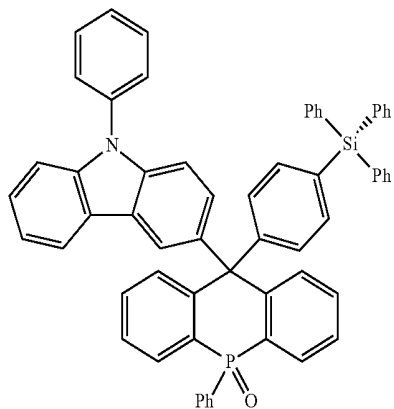
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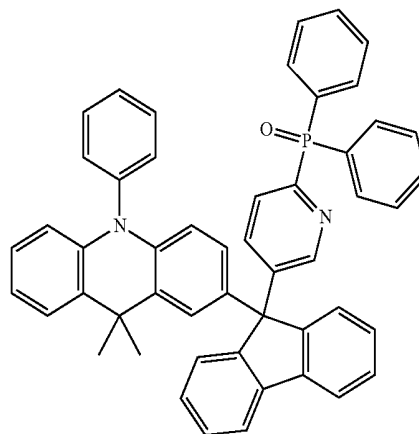
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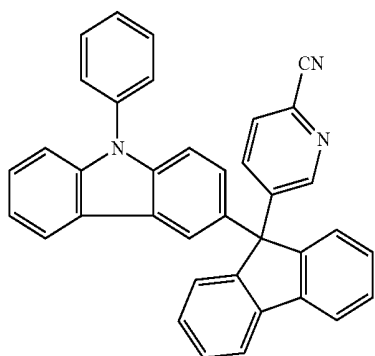
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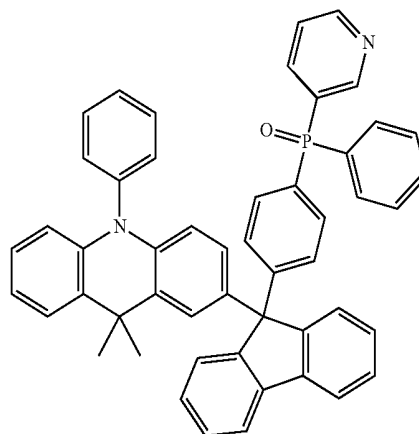
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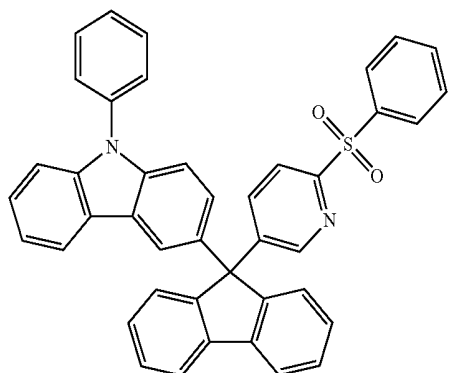


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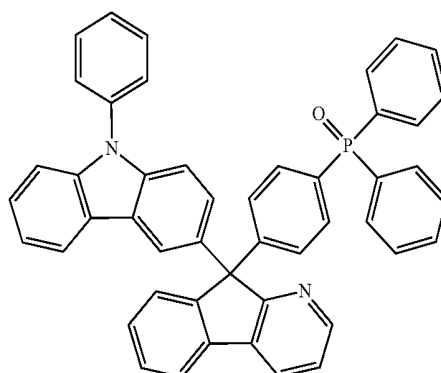
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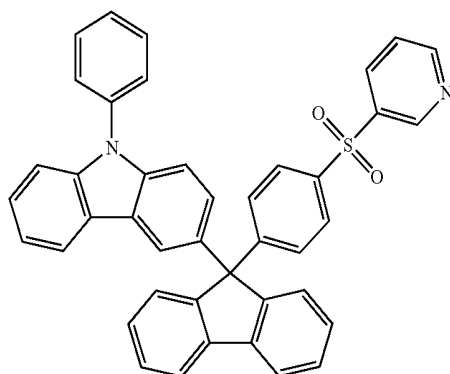


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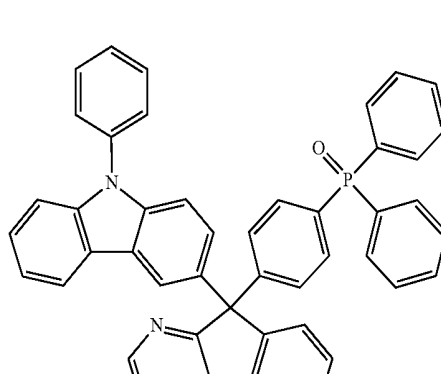
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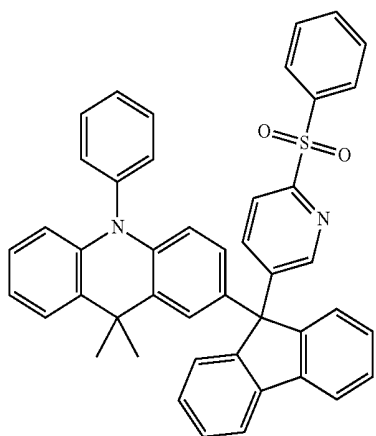
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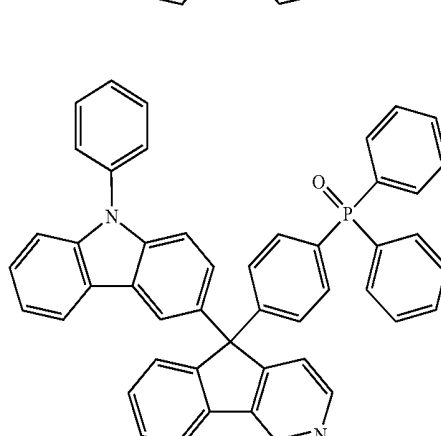
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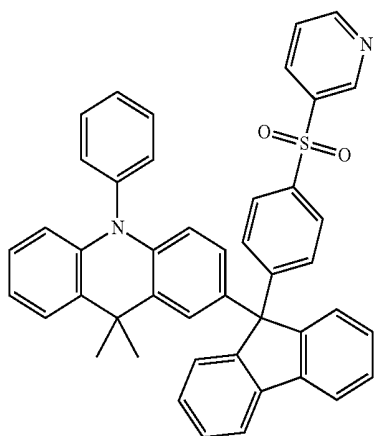
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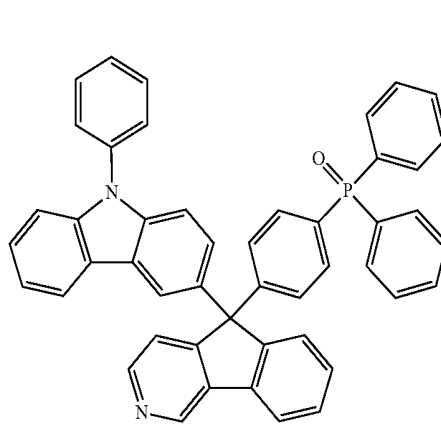
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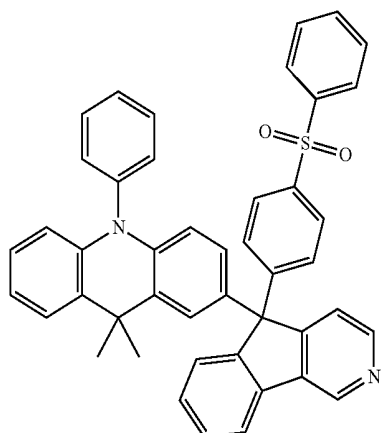


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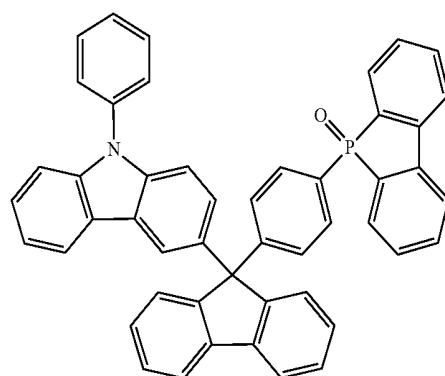
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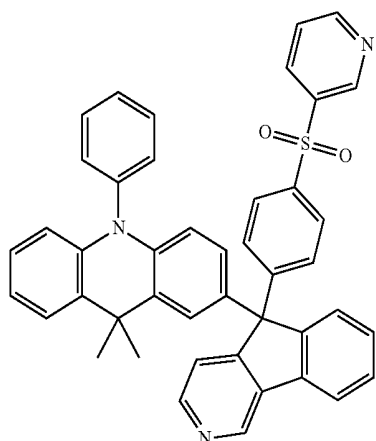


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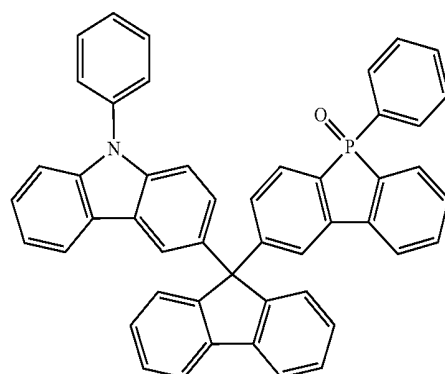
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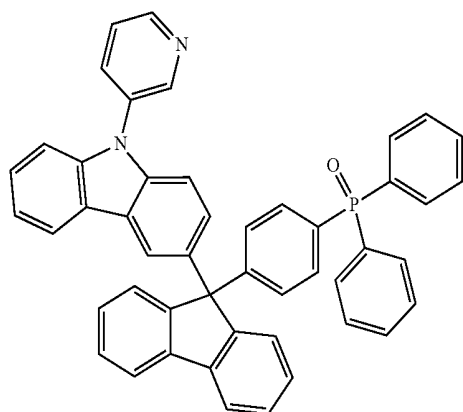
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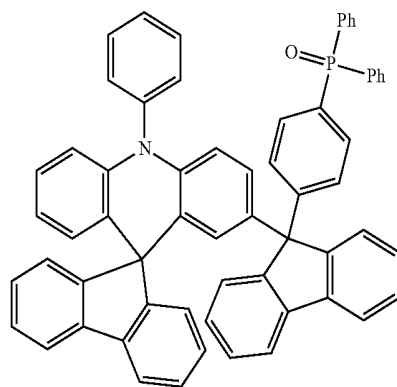
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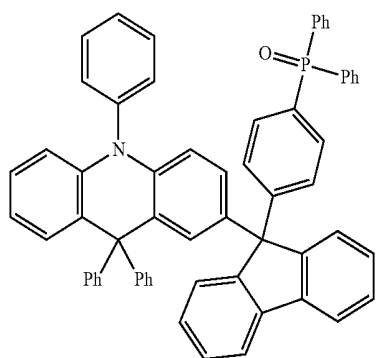
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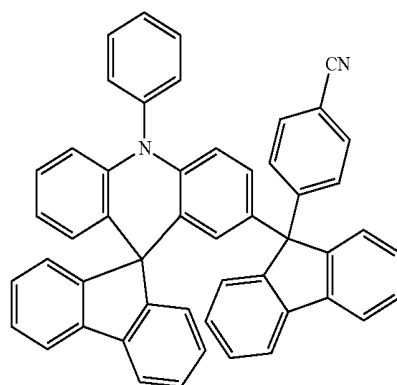
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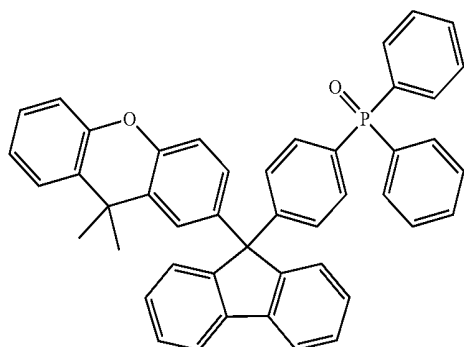


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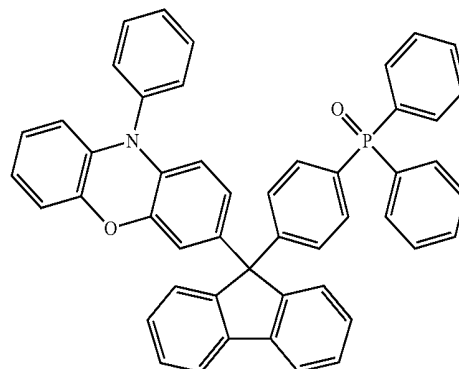
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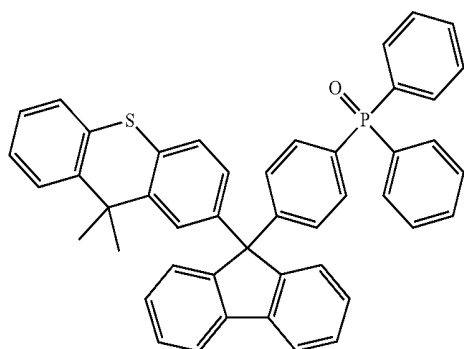


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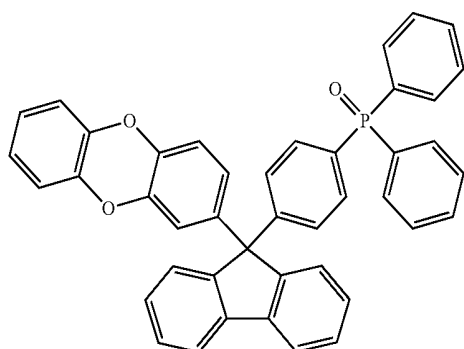
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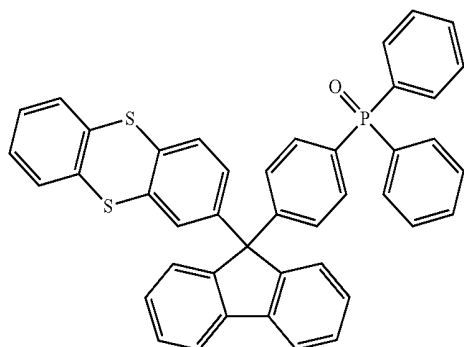
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[0122] The condensed cyclic compound represented by Formula 1 may include structures defined in Formulae 1 and 2. In particular, the condensed cyclic compound is characterized by comprising different substituents bound to a fluorene-based core. The fluorene-based core limits the intermolecular rotation, thereby achieving a high glass transition temperature. The substituents bound to the fluorene-based core have hole transportability and electron transportability, and enable the synthesis of an organic electronic material having various degrees of charge transportability depending on the combination.

[0123] In an exemplary embodiment, the condensed cyclic compound represented by Formula 1 may include at least one selected from a cyano group, $-\text{Si}(\text{Ar}_1)(\text{Ar}_2)(\text{Ar}_3)$, $-\text{S}(=\text{O})_2(\text{Ar}_1)$, and $-\text{P}(=\text{O})(\text{Ar}_1)(\text{Ar}_2)$, thereby having a high triplet-state energy. Further, by combining the fluorene-based core and other substituents, the condensed cyclic compound represented by Formula 1 may have a relatively low triplet-state energy and a relatively low singlet-state energy. Thus, the condensed cyclic compound may be used as an energetically stable host or exhibit thermally activated delayed fluorescence. Furthermore, the condensed cyclic compound represented by Formula 1 may have hole- or electron-transporting ability, to thereby increase exciton formation efficiency in an emission layer of an organic light-emitting device including the condensed cyclic compound represented by Formula 1. Accordingly, such an organic light-emitting device may have low driving voltage and high efficiency.

[0124] A synthesis method for the condensed cyclic compound represented by Formula 1 would be apparent to one of skill in the art by referring to the following examples.

[0125] At least one of the condensed cyclic compounds represented by Formula 1 may be used between a pair of electrodes constituting an organic light-emitting device. For example, the condensed cyclic compound represented by Formula 1 may be included in at least one layer selected from a hole transport region, an electron transport region, and an emission layer. In an exemplary embodiment, the condensed cyclic compound represented by Formula 1 may be used as a material for forming a capping layer located outside a pair of electrodes of an organic light-emitting device.

[0126] According to another aspect of embodiments, an organic light-emitting device may include: a first electrode; a second electrode facing the first electrode; and an organic layer between the first electrode and the second electrode, the organic layer including an emission layer and at least one of the condensed cyclic compounds represented by Formula 1.

[0127] The expression “(an organic layer) includes at least one of the condensed cyclic compounds” used herein may

include a case in which “(an organic layer) includes identical condensed cyclic compounds represented by Formula 1” and a case in which “(an organic layer) includes two or more different condensed cyclic compounds represented by Formulae 1A to 1H.”

[0128] In an exemplary embodiment, in the organic light-emitting device, the first electrode may be an anode, the second electrode may be a cathode, and the organic layer may include a hole transport region between the first electrode and the emission layer and an electron transport region between the emission layer and the second electrode, wherein the hole transport region may include a hole injection layer, a hole transport layer, emission auxiliary layer, an electron blocking layer, or any combination thereof, and the electron transport region may include a buffer layer, a hole blocking layer, an electron control layer, an electron transport layer, an electron injection layer, or any combination thereof.

[0129] In an exemplary embodiment, the emission layer may include a dopant and a host, wherein the dopant may include at least one of the condensed cyclic compounds represented by Formula 1.

[0130] In an exemplary embodiment, the host in the emission layer may include at least one selected from an anthracene-based compound, a pyrene-based compound, and a spiro-bifluorene-based compound, but the embodiments are not limited thereto.

[0131] In an exemplary embodiment, the emission layer may include a dopant and a host, wherein the host may include at least one of the condensed cyclic compounds represented by Formula 1.

[0132] In an exemplary embodiment, the dopant in the emission layer may include at least one of a styryl-based compound and an amine-based compound, but the embodiments are not limited thereto.

[0133] In an exemplary embodiment, the emission layer of the organic light-emitting device may be a first color light-emitting layer,

[0134] the organic light-emitting device may include, between the first electrode and the second electrode, i) at least one second color light-emitting layer or ii) at least one second color light-emitting layer and at least one third color light-emitting layer,

[0135] a maximum emission wavelength of the first color light-emitting layer, a maximum emission wavelength of the second color light-emitting layer, and a maximum emission wavelength of the third color light-emitting layer are the same as or different from each other, and

[0136] the first color light and the second color light are emitted in the form of mixed light, or the first color light, the second color light, and the third color light are emitted in the form of mixed light.

[0137] The organic light-emitting device may further include at least one selected from a first capping layer disposed in a pathway along which light generated in an emission layer proceeds toward the outside through the first electrode and a second capping layer disposed in a pathway along which light generated in an emission layer proceeds toward the outside through the second electrode, and at least one of the first capping layer and the second capping layer may include at least one of the condensed cyclic compounds represented by Formula 1.

[0138] In an exemplary embodiment, the organic light-emitting device may have i) a stack structure including a first electrode, an organic layer, a second electrode, and a second capping layer which are sequentially stacked in this stated order, ii) a stack structure including a first electrode, an organic layer, and a second electrode which are sequentially stacked in this stated order, iii) a stack structure including a first capping layer, a first electrode, an organic layer, a

second electrode, and a second capping layer which are sequentially stacked in this stated order, wherein at least one of the first capping layer and the second capping layer may include the condensed cyclic compound represented by Formula 1.

[0139] The term “organic layer” used herein refers to a single layer and/or a plurality of layers disposed between the first electrode and the second electrode of the organic light-emitting device. A material included in the “organic layer” is not limited to an organic material.

[Description of FIG. 1]

[0140] FIG. 1 is a schematic view of an organic light-emitting device 10 according to an exemplary embodiment. The organic light-emitting device 10 includes a first electrode 110, an organic layer 150, and a second electrode 190.

[0141] A structure of the organic light-emitting device 10 according to an exemplary embodiment and a method of the organic light-emitting device 10 according to an exemplary embodiment will be described in more detail below with reference to FIG. 1.

[First Electrode 110]

[0142] Referring to FIG. 1, a substrate may be additionally disposed below the first electrode 110. Alternatively, the substrate may be disposed above the second electrode 190. The substrate may include a glass substrate or a plastic substrate. The glass substrate and the plastic substrate may each have a relatively high mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and water-resistance.

[0143] The first electrode 110 may be formed by, for example, depositing or sputtering a material included in the first electrode 110 on the substrate. When the first electrode 110 is an anode, the material included in the first electrode 110 may include materials with a relatively high work function which may facilitate hole injection.

[0144] The first electrode 110 may be a reflective electrode, a semi-transmissive electrode, or a transmissive electrode. When the first electrode 110 is a transmissive electrode, a material included in the first electrode 110 may include indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO₂), zinc oxide (ZnO), or any combination thereof, but the embodiments are not limited thereto. When the first electrode 110 is a semi-transmissive electrode or a reflective electrode, a material included in the first electrode 110 may include magnesium (Mg), silver (Ag), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), magnesium-silver (Mg—Ag), and or any combination thereof, but the embodiments are not limited thereto.

[0145] The first electrode 110 may have a single-layered structure. Alternatively, the first electrode 110 may have 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 embodiments are not limited thereto.

[Organic Layer 150]

[0146] The organic layer 150 may be disposed on the first electrode 110. The organic layer 150 may include an emission layer.

[0147] The organic layer 150 may include a hole transport region and an electron transport region. The hole transport region may be disposed between the first electrode 110 and the emission layer, and the electron transport region may be disposed between the emission layer and the second electrode 190.

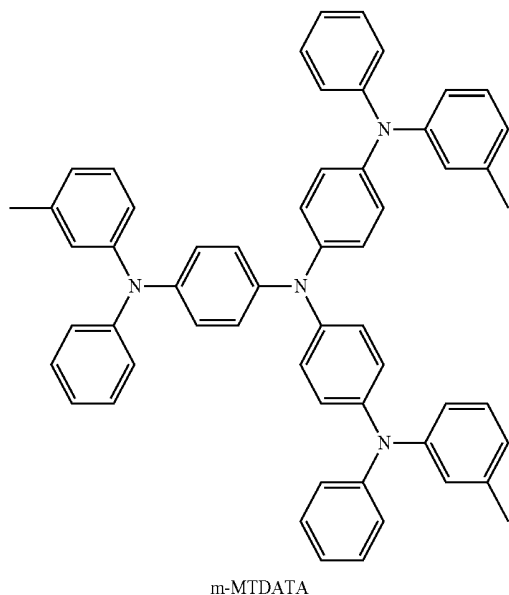
[Hole Transport Region in Organic Layer 150]

[0148] The hole transport region may have i) a single-layered structure 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.

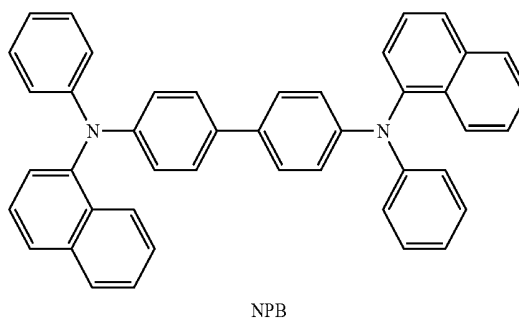
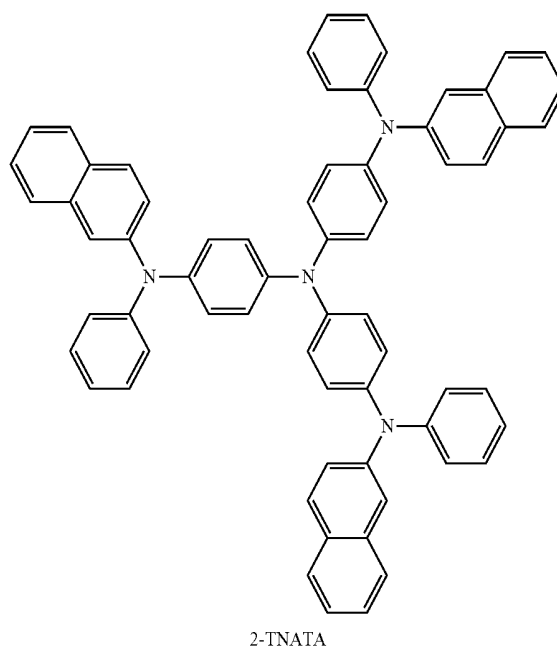
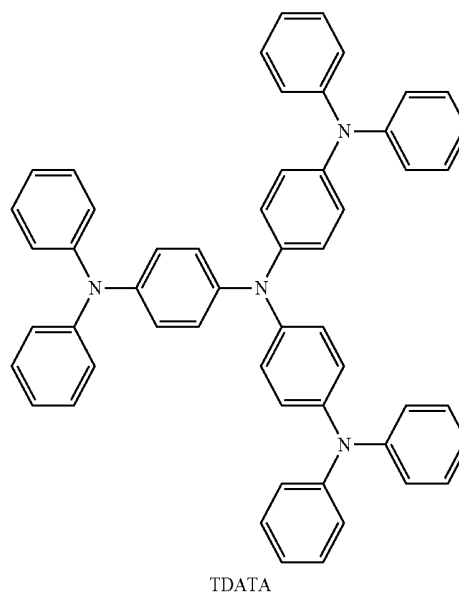
[0149] The hole transport region may include at least one layer selected from a hole injection layer, a hole transport layer, an emission auxiliary layer, and an electron blocking layer.

[0150] For example, the hole transport region may have a single-layered structure, wherein the single-layered structure may include a single layer including a plurality of different materials. Alternatively, the hole transport region may have a multi-layered structure, wherein the multi-layered structure may include a hole injection/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. For each structure, the layers may be sequentially stacked on the first electrode 110 in this stated order, but the embodiments are not limited thereto.

[0151] The hole transport region may include at least one selected from m-MTDATA, TDATA, 2-TNATA, NPB (NPD), β -NPB, TPD, spiro-TPD, spiro-NPB, methylated-NPB, TAPC, HMTPD, 4,4',4''-tris(N-carbazolyl)triphenylamine (TCTA), polyaniline/dodecylbenzenesulfonic acid (PANI/DBSA), poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate) (PEDOT/PSS), polyaniline/camphor sulfonic acid (PANI/CSA), polyaniline/poly(4-styrenesulfonate) (PANI/PSS), a group represented by Formula 201, and a group represented by Formula 202:



-continued



[0155] xa1 to xa4 may each independently be an integer of 0 to 3,

[0156] xa5 may be an integer of 1 to 10, and

[0157] R₂₀₁ to R₂₀₄ and Q₂₀₁ may each independently be selected from a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₁-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group.

[0158] For example, in Formula 202, R₂₀₁ and R₂₀₂ may optionally be linked via a single bond, a dimethyl-methylene group, or a diphenyl-methylene group, and R₂₀₃ and R₂₀₄ may optionally be linked via a single bond, a dimethyl-methylene group, or a diphenyl-methylene group.

[0159] In an exemplary embodiment, in Formulae 201 and 202,

[0160] L₂₀₁ to L₂₀₅ may each independently be selected from:

[0161] a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene 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 fluoranthrenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a rubicenylene group, a coronenylene group, an ovalenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, and a pyridinylene group; and

[0162] a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene 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 fluoranthrenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a rubicenylene group, a coronenylene group, an ovalenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, and a pyridinylene 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 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 benzofuranlyl group, a benzothiophenyl group, a dibenzofuranlyl 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

[0163] 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] In an exemplary embodiment, xa1 to xa4 in Formulae 201 and 202 may each independently be 0, 1, or 2.

[0165] In an exemplary embodiment, xa5 may be 1, 2, 3, or 4.

[0166] In an exemplary embodiment, R₂₀₁ to R₂₀₄ and Q₂₀₁ 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 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 benzofuranlyl group, a benzothiophenyl group, a dibenzofuranlyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group; and

[0167] 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 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 benzofuranlyl group, a benzothiophenyl group, a dibenzofuranlyl 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 dibenzofluore-

nyl 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, $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, and $-\text{N}(\text{Q}_{31})(\text{Q}_{32})$,

[0168] Q_{31} to Q_{33} may each independently be the same as defined herein.

[0169] In an exemplary embodiment, in Formula 201, at least one selected from R_{201} to R_{203} may be selected from:

[0170] a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

[0171] 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, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a 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 $-\text{F}$, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, but the embodiments are not limited thereto.

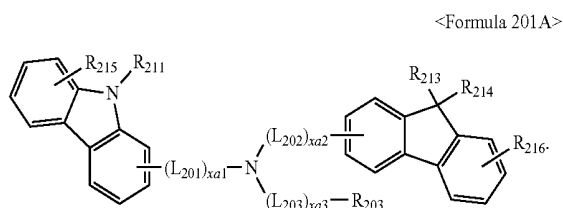
[0172] In an exemplary embodiment, in Formula 202, i) R_{201} and R_{202} may be linked via a single bond, and/or ii) R_{203} and R_{204} may be linked via a single bond.

[0173] In an exemplary embodiment, in Formula 202, at least one selected from R_{201} to R_{204} may be selected from:

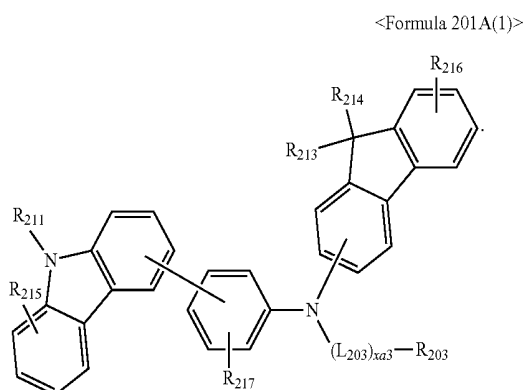
[0174] a carbazolyl group; and

[0175] a carbazolyl group substituted with at least one selected from deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a 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 $-\text{F}$, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, but the embodiments are not limited thereto.

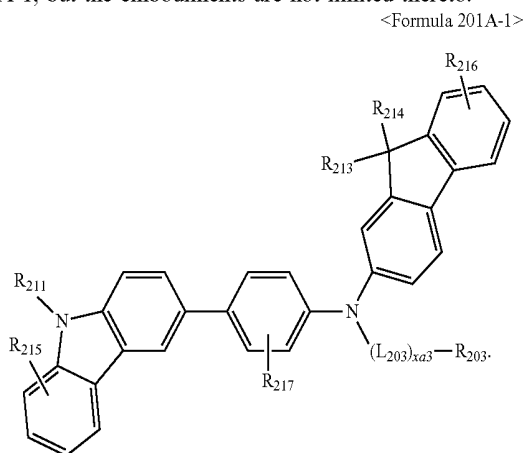
[0176] The compound represented by Formula 201 may be represented by Formula 201A:



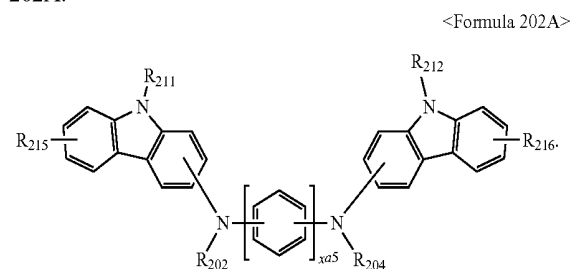
[0177] In an exemplary embodiment, the compound represented by Formula 201 may be represented by Formula 201A(1), but the embodiments are not limited thereto:



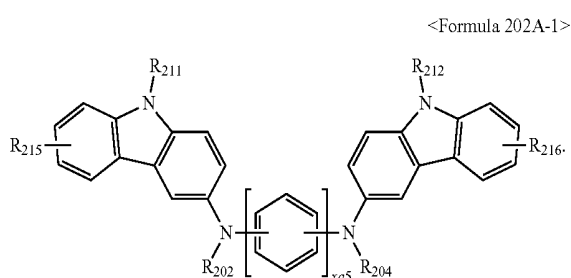
[0178] In an exemplary embodiment, the compound represented by Formula 201 may be represented by Formula 201A-1, but the embodiments are not limited thereto:



[0179] In an exemplary embodiment, the compound represented by Formula 202 may be represented by Formula 202A:



[0180] In an exemplary embodiment, the compound represented by Formula 202 may be represented by Formula 202A-1:



[0181] In Formulae 201A, 201A(1), 201A-1, 202A, and 202A-1,

[0182] L_{201} to L_{203} , $xa1$ to $xa3$, $xa5$, and R_{202} to R_{204} may each independently be the same as described above,

[0183] R_{211} and R_{212} may each independently be the same as R_{203} ,

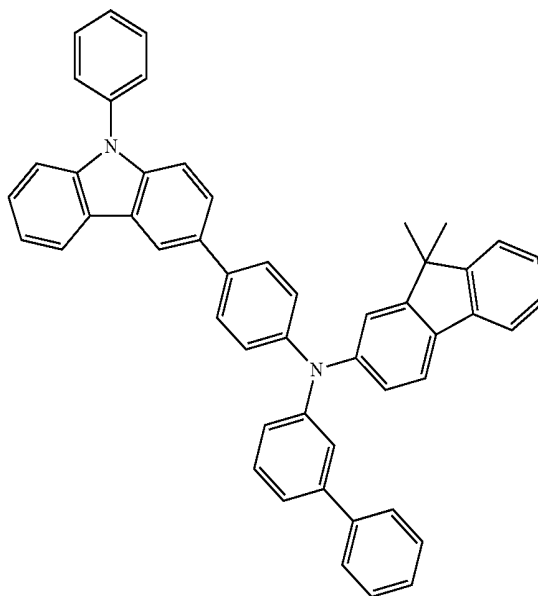
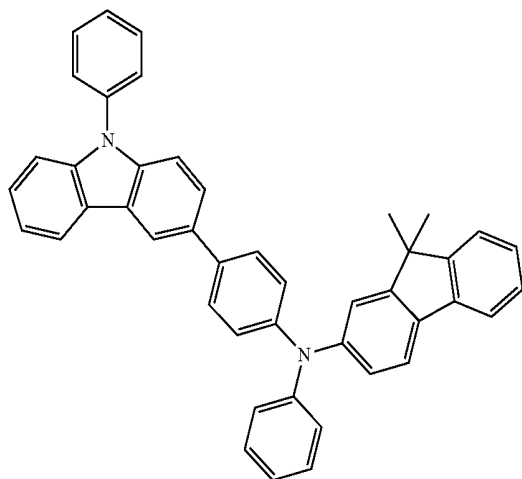
[0184] R_{213} to R_{217} may each independently be selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a 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 acenaph-

thyl 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.

[0185] In an exemplary embodiment, the hole transport region may include at least one compound selected from Compounds HT1 to HT39, but the embodiments are not limited thereto:

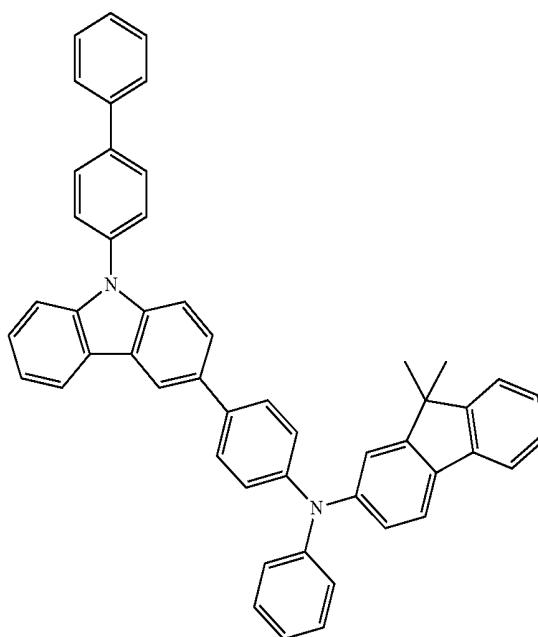
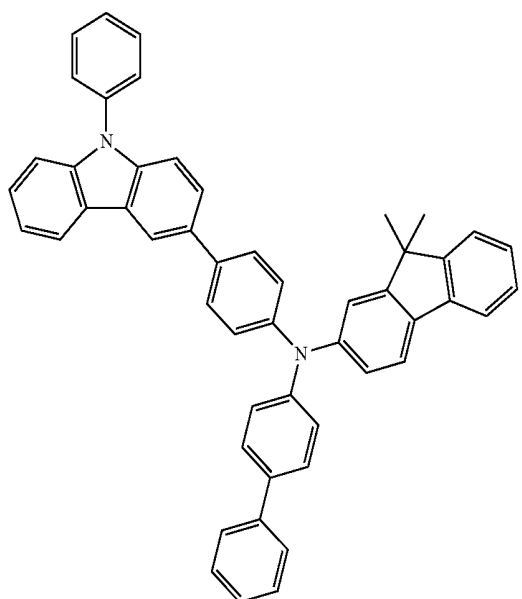
HT1

HT2



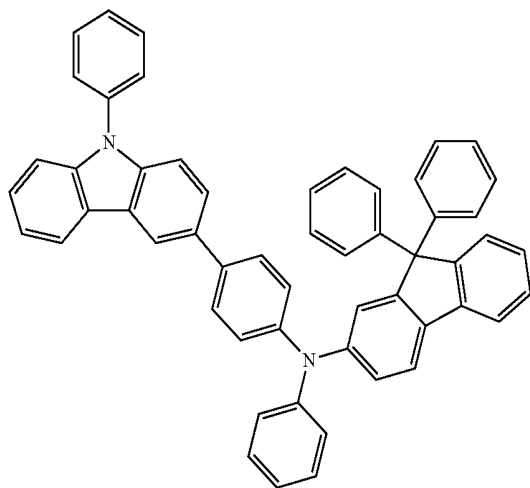
HT3

HT4

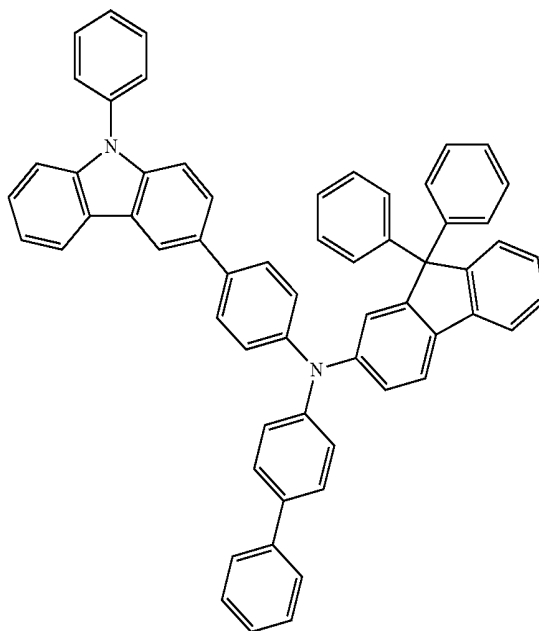


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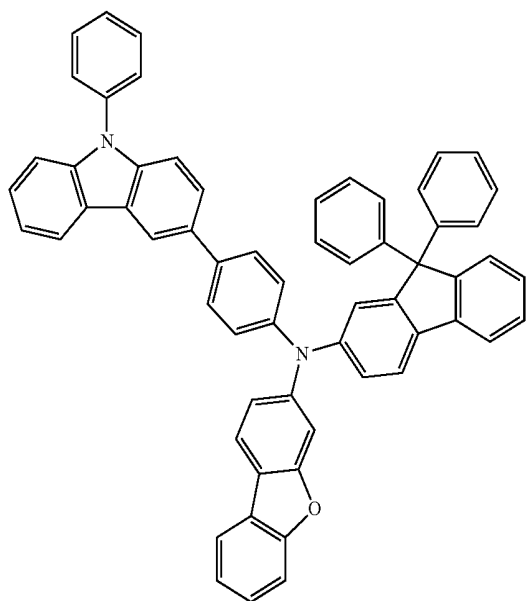
HT5



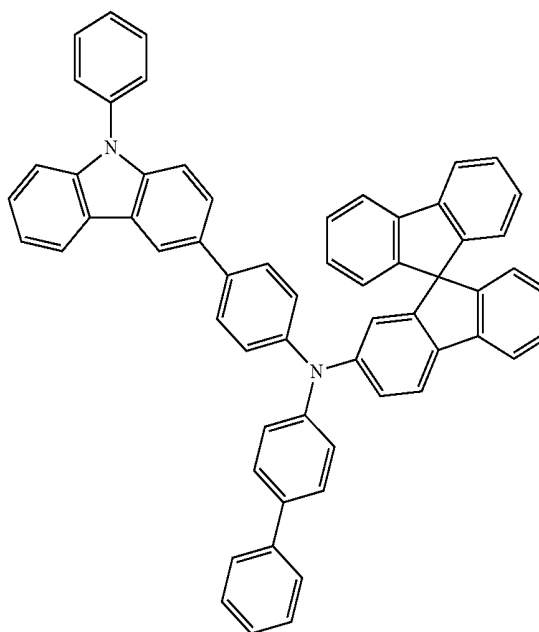
HT6



HT7

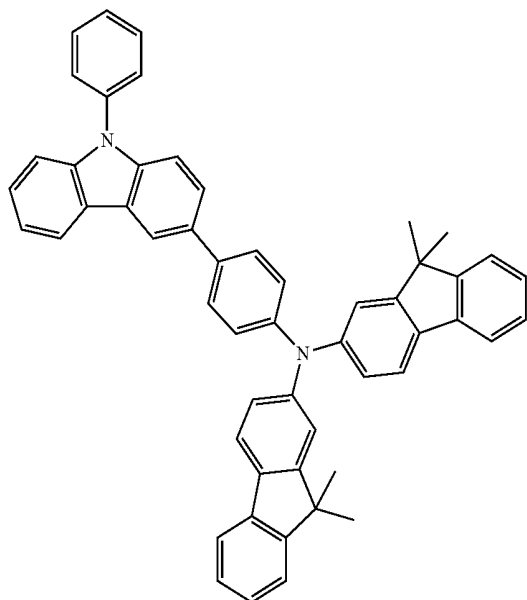


HT8

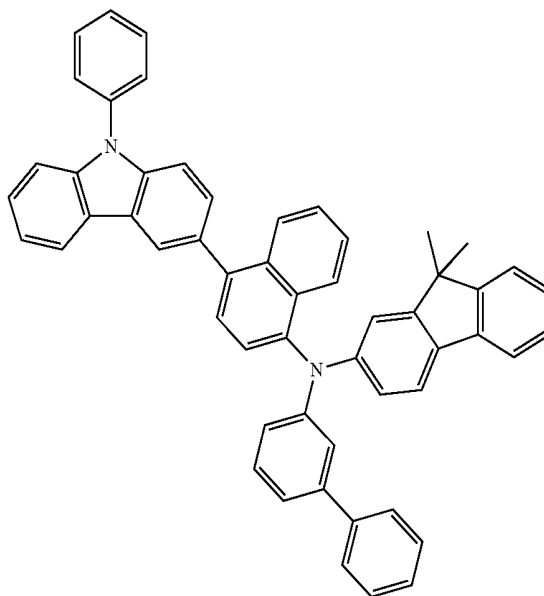


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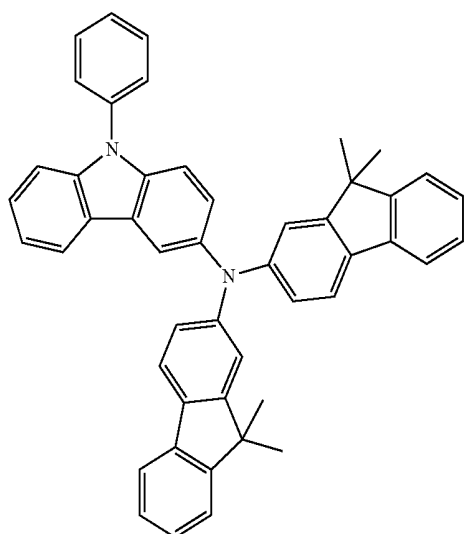
HT9



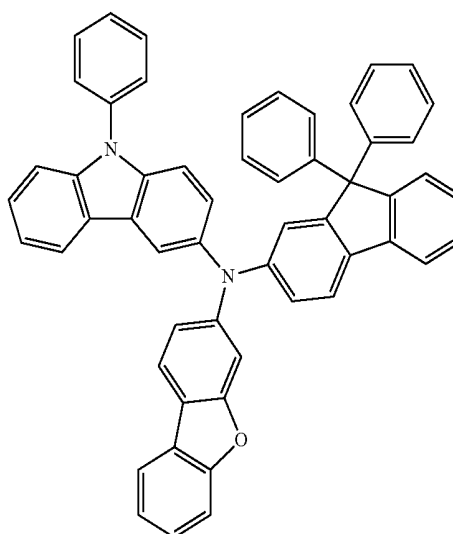
HT10



HT11



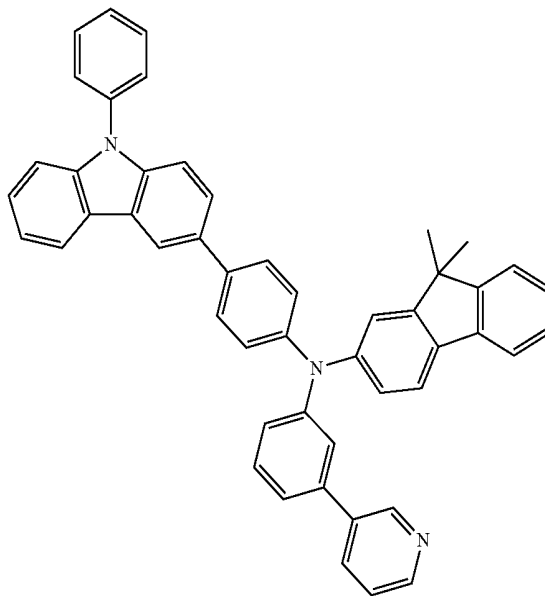
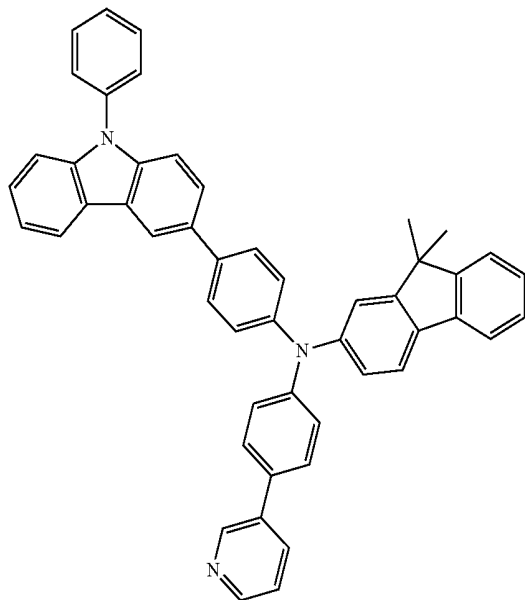
HT12



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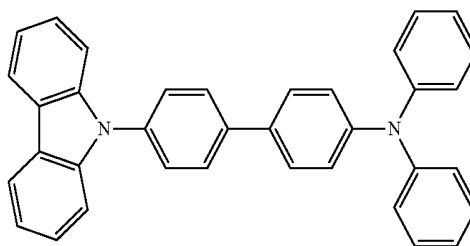
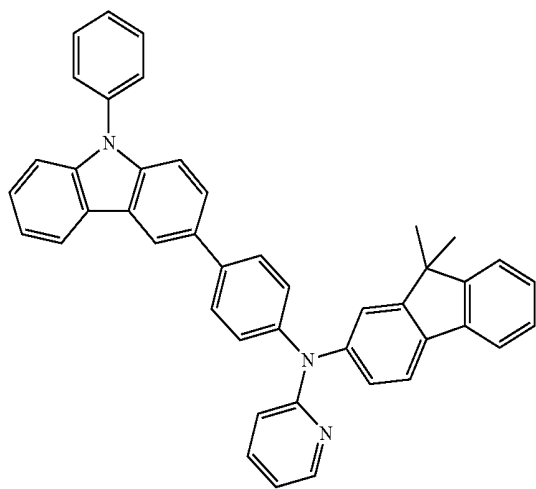
HT13

HT14



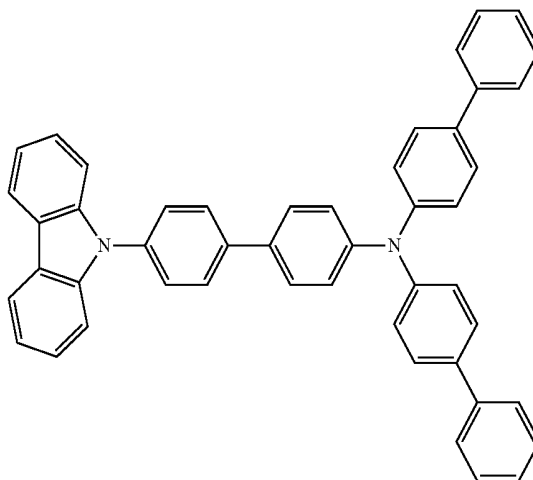
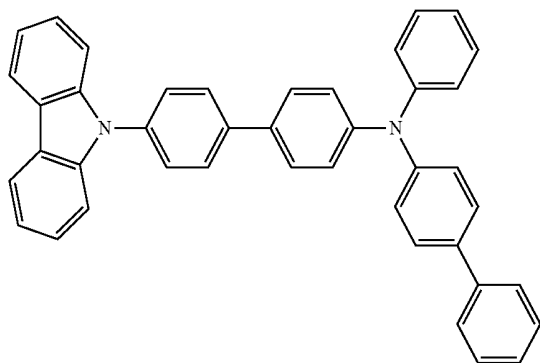
HT15

HT16



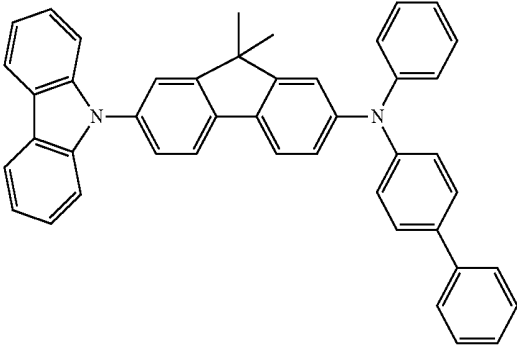
HT17

HT18

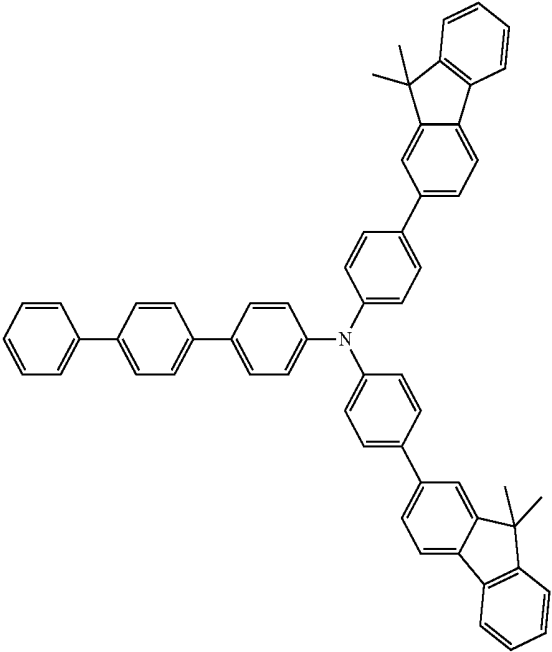


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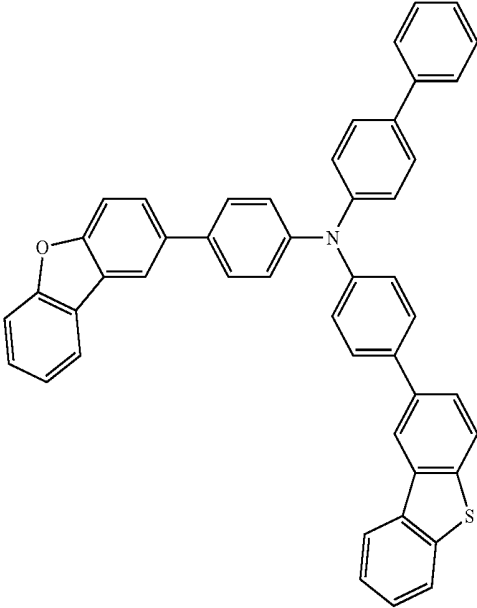
HT19



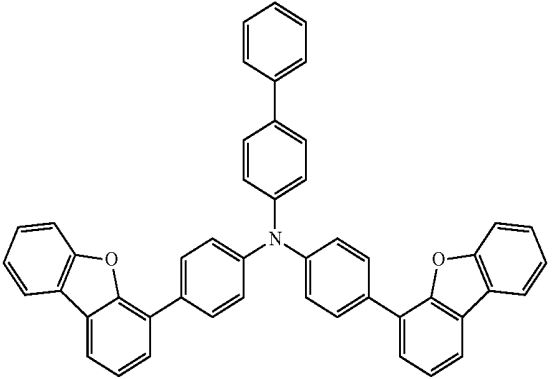
HT20



HT21

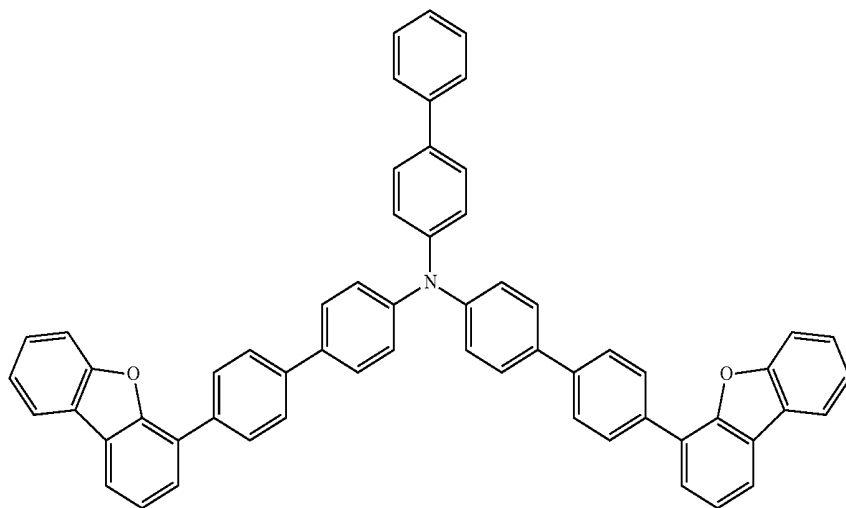


HT22

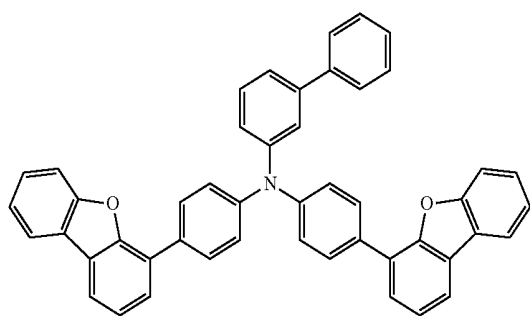


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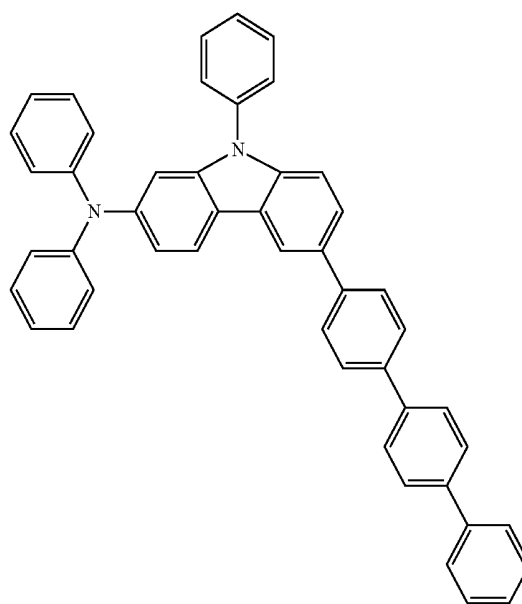
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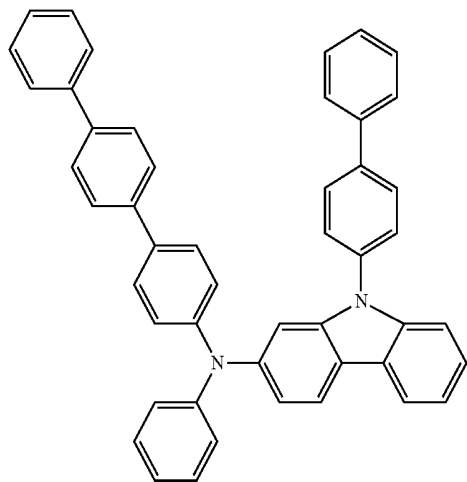
HT24



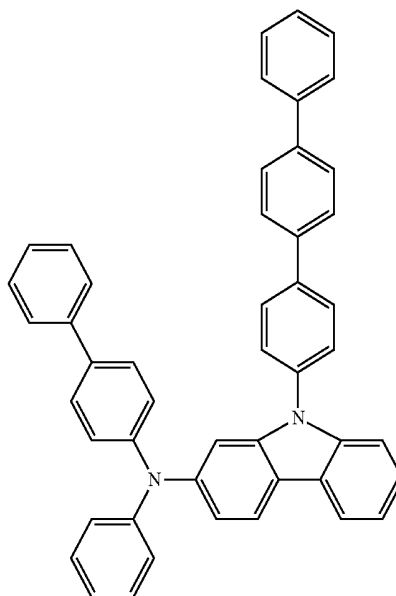
HT25



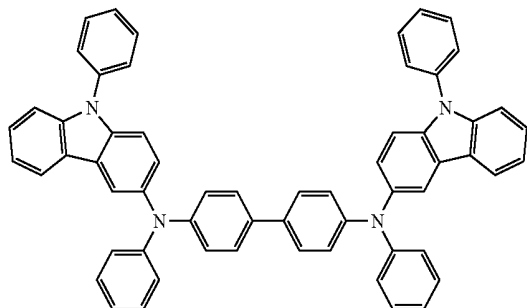
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HT26



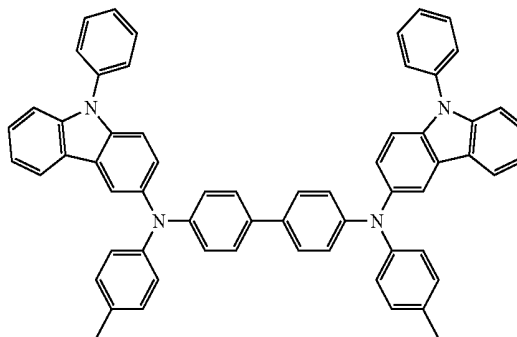
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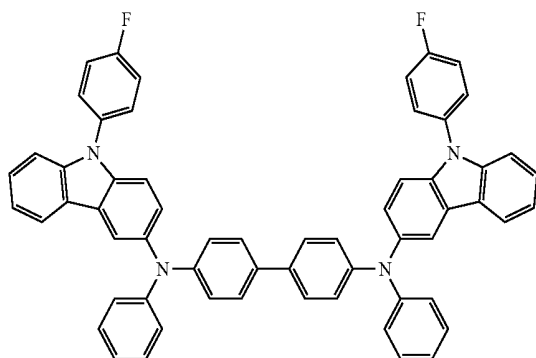
HT28



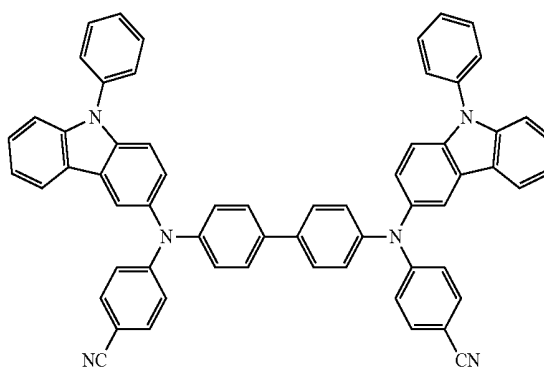
HT29



HT30

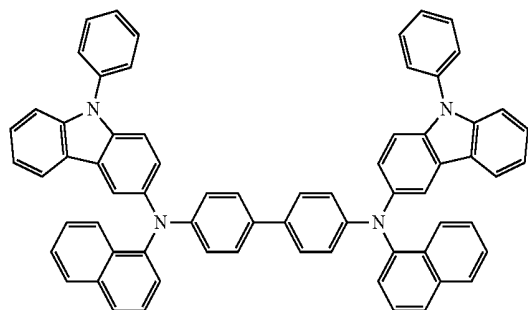


HT31

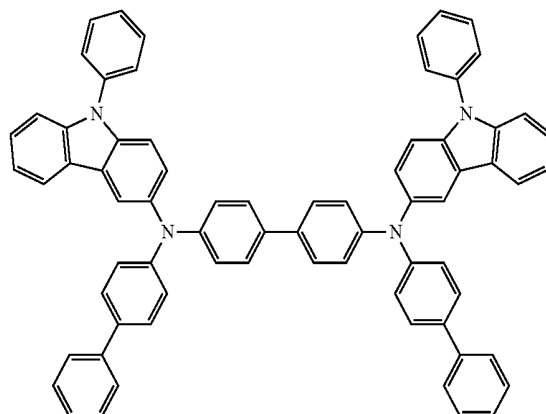


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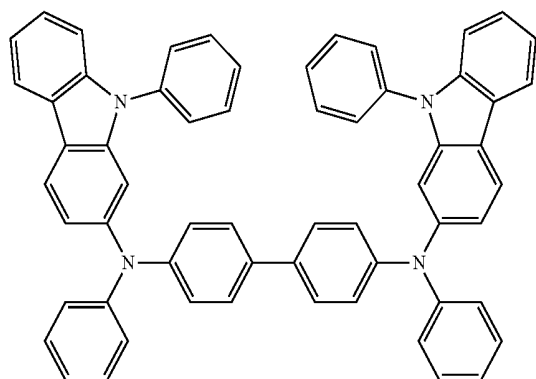
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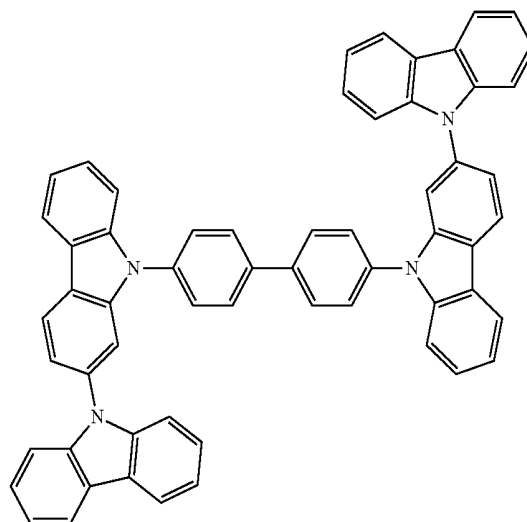
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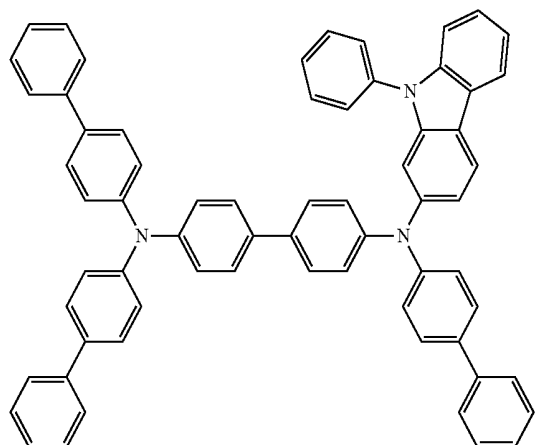
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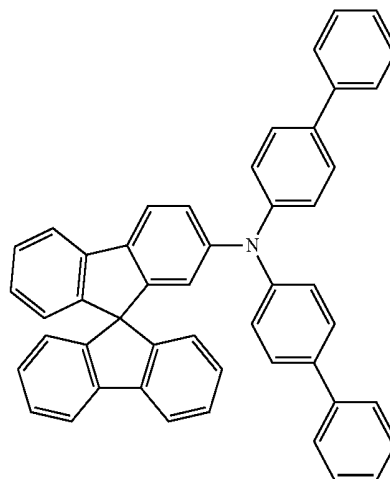
HT35



HT36

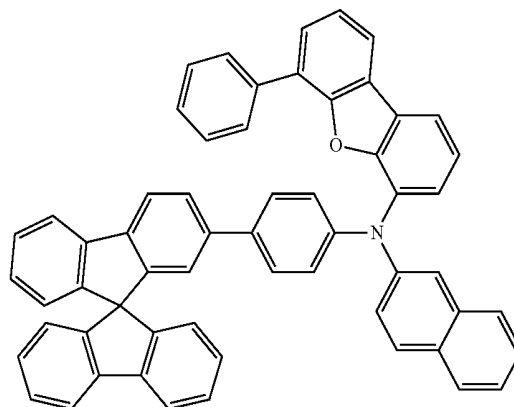
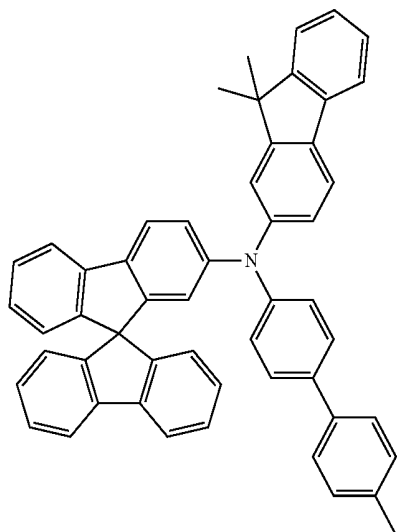


HT37



-continued
HT38

HT39



[0186] A thickness of the hole transport region may be in a range of from about 100 Å to about 10,000 Å, for example, from about 100 Å to about 1,000 Å. When the hole transport region includes at least one of a hole injection layer and a hole transport layer, a thickness of the hole injection layer may be in a range of from 100 Å to about 9,000 Å, for example, about 100 Å to about 1,000 Å, and a thickness of the hole transport layer may be in a range of from about 50 Å to about 2,000 Å, for example, about 100 Å to about 1,500 Å. When the thicknesses of the hole transport region, the hole injection layer, and the hole transport layer are within any of these ranges, satisfactory hole transporting characteristics may be obtained without a substantial increase in driving voltage.

[0187] The emission auxiliary layer may compensate for an optical resonance distance according to a wavelength of light emitted from the emission layer. Thus, the light-emission efficiency of a formed organic light-emitting device may be increased. The electron blocking layer may decrease or prevent injection of electrons from the second transport region. The emission auxiliary layer and the electron blocking layer may include materials as described herein.

[P-Dopant]

[0188] The hole transport region may include, in addition to the materials described above, a charge-generation material, which may increase conductive properties of the hole transport region. The charge-generation material may be substantially homogeneously or non-homogeneously dispersed in the hole transport region.

[0189] The charge-generation material may be, for example group, a p-dopant.

[0190] In an exemplary embodiment, a lowest unoccupied molecular orbital (LUMO) of the p-dopant may be -3.5 eV or less.

[0191] In an exemplary embodiment, the p-dopant may be one of a quinone derivative, a metal oxide, and a compound containing a cyano group, but the embodiments are not limited thereto.

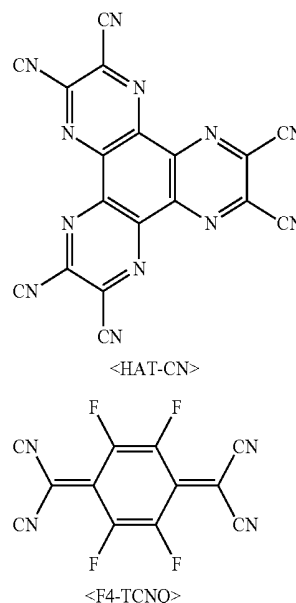
[0192] In an exemplary embodiment, the p-dopant may include at least one selected from:

[0193] a quinone derivative, such as tetracyanoquinonedi-methane (TCNQ) and 2,3,5,6-tetrafluoro-tetracyano-1,4-benzoquinonedi-methane (F4-TCNQ);

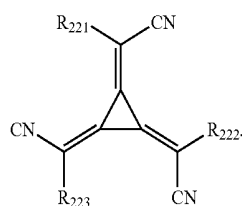
[0194] a metal oxide, such as a tungsten oxide and a molybdenum oxide;

[0195] a compound containing a cyano group, such as 1,4,5,8,9,11-hexaazatriphenylene-hexacarbonitrile (HAT-CN); and

[0196] compound represented by Formula 221, but the embodiments are not limited thereto:



-continued



<Formula 221>

[0197] In Formula 221,

[0198] 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 aryl group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, wherein at least one selected from R₂₂₁ to R₂₂₃ may include a 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]

[0199] 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, and/or a blue emission layer, according to a sub-pixel. In an exemplary embodiment, the emission layer may have a stacked structure. The stacked structure may include two or more layers selected from a red emission layer, a green emission layer, and a blue emission layer, wherein the two or more layers may be in direct contact with each other or may be separated from each other. In an exemplary embodiment, the emission layer may include two or more materials, wherein the two or more materials may include a red light-emitting material, a green light-emitting material, and a blue light-emitting material. The two or more materials may be mixed with each other in a single layer, and accordingly, may emit light.

[0200] The emission layer may include a host and a dopant. The dopant may include at least one of a phosphorescent dopant and a fluorescent dopant.

[0201] The emission layer may include at least one of the condensed cyclic compounds represented by Formula 1.

[0202] An amount of the above dopant in the emission layer may be in a range of from about 0.01 parts by weight to about 15 parts by weight based on 100 parts by weight of the host, but the embodiments are not limited thereto.

[0203] A thickness of the emission layer may be in a range of from about 100 Å to about 1,000 Å, for example, from about 200 Å to about 600 Å. When the thickness of the emission layer is within any of these ranges, increased light-emission characteristics may be obtained without a substantial increase in driving voltage.

[Host in Emission Layer]

[0204] The host may include the condensed cyclic compound represented by Formula 1.

[Ar₃₀₁]_{xb11}-(L₃₀₁)_{xb1}-R₃₀₁_{kb21}

<Formula 301>

[0205] In Formula 301,

[0206] Ar₃₀₁ may be a substituted or unsubstituted C₅-C₆₀ carbocyclic group or a substituted or unsubstituted C₁-C₆₀ heterocyclic group,

[0207] xb11 may be 1, 2, or 3,

[0208] L₃₀₁ may 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-C₆₀ arylene group, a substituted or unsubstituted C₁-C₆₀ heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0209] xb1 may be an integer of 0 to 5,

[0210] R₃₀₁ may be selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₂-C₆₀ alkenyl group, a substituted or unsubstituted C₂-C₆₀ alkynyl group, a substituted or unsubstituted C₁-C₆₀ alkoxy group, a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(Q₃₀₁)(Q₃₀₂)(Q₃₀₃), —N(Q₃₀₁)(Q₃₀₂), —B(Q₃₀₁)(Q₃₀₂), —C(=O)(Q₃₀₁), —S(=O)₂(Q₃₀₁), and —P(=O)(Q₃₀₁)(Q₃₀₂),

[0211] xb21 may be an integer of 1 to 5, and

[0212] Q₃₀₁ to Q₃₀₃ may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, but the embodiments are not limited thereto.

[0213] In an exemplary embodiment, in Formula 301, Ar₃₀₁ may be selected from:

[0214] a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group and a dibenzothioophene group; and

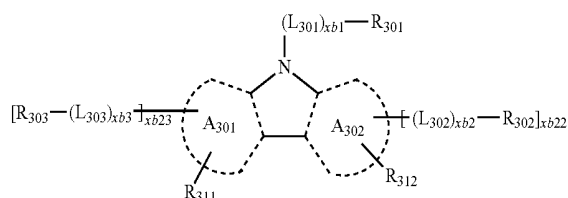
[0215] a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, and a dibenzothioophene group, each substituted with at least one

selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂), and

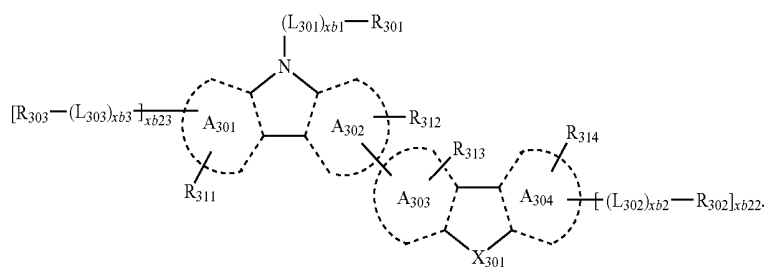
[0216] Q₃₁ to Q₃₃ may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, but the embodiments are not limited thereto.

[0217] In Formula 301, when xb1 may be 2 or greater, at least two Ar₃₀₁(s) may be linked via a single bond.

[0218] In an exemplary embodiment, the compound represented by Formula 301 may be represented by Formulae 301-1 or 301-2:



<Formula 301-1>



<Formula 301-2>

[0219] In Formulae 301-1 to 301-2,

[0220] A₃₀₁ to A₃₀₄ may each independently be selected from a benzene group, a naphthalene group, a phenanthrene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a pyridine group, a pyrimidine group, an indene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, an indole group, a carbazole group, a benzocarbazole group, a dibenzocarbazole group, a furan group, a benzofuran group, a dibenzofuran group, a naphthofuran group, a benzonaphthofuran group, a dinaphthofuran group, a thiophene group, a benzothiophene group, a dibenzothiophene group, a naphthothiophene group, a benzonaphthothiophene group, and a dinaphthothiophene group,

[0221] X₃₀₁ may be O, S, or N—[(L₃₀₄)_{xb4}—R₃₀₄],

[0222] R₃₁₁ to R₃₁₄ may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂),

[0223] xb22 and xb23 may each independently be 0, 1, or 2,

[0224] L₃₀₁, xb1, R₃₀₁, and Q₃₁ to Q₃₃ may each independently be the same as defined herein,

[0225] L₃₀₂ to L₃₀₄ may each independently be the same as L₃₀₁,

[0226] Xb2 to xb4 may each independently be the same as xb1, and

[0227] R₃₀₂ to R₃₀₄ may each independently be the same as R₃₀₁.

[0228] In an exemplary embodiment, in Formulae 301, 301-1, and 301-2, L₃₀₁ to L₃₀₄ may each independently be selected from:

[0229] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylylene group, a fluoranthenylylene group, a triphenylenylene group, a pyrenylene group, a

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

[0230] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylylene group, a dibenzofluorenylylene group, a phenanthre-

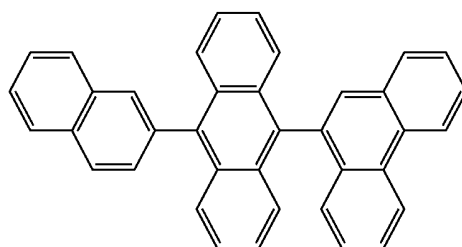
pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an azacarbazolyl group, $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, $-\text{N}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{B}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{C}(=\text{O})(\text{Q}_{31})$, $-\text{S}(=\text{O})_2(\text{Q}_{31})$, and $-\text{P}(=\text{O})(\text{Q}_{31})(\text{Q}_{32})$, and

[0235] Q_{31} to Q_{33} may each independently be the same as defined herein.

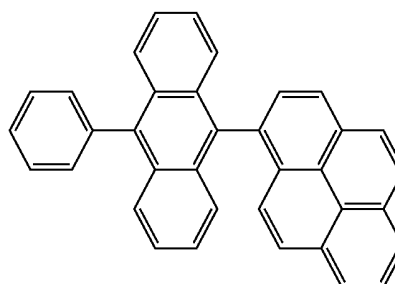
[0236] In an exemplary embodiment, the host may include an alkali metal complex. In an exemplary embodiment, the host may include at least one selected from a beryllium (Be) compound (e.g., Compound H55), a Mg complex, and a Zn complex.

[0237] In an exemplary embodiment, the host may include at least one selected from 9,10-di(2-naphthyl)anthracene (ADN), 2-methyl-9,10-bis(naphthalen-2-yl)anthracene (MADN), 9,10-di-(2-naphthyl)-2-t-butyl-anthracene (TBADN), 4,4'-bis(N-carbazolyl)-1,1'-biphenyl (CBP), 1,3-di-9-carbazolylbenzene (mCP), 1,3,5-tri(carbazol-9-yl)benzene (TCP), and Compounds H1 to H55, but the embodiments are not limited thereto:

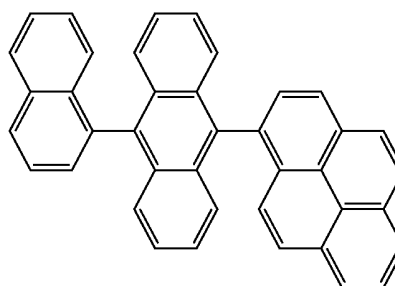
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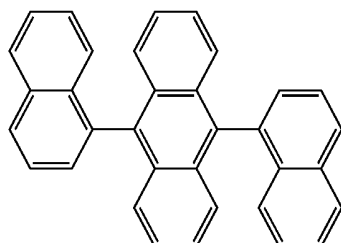
H4



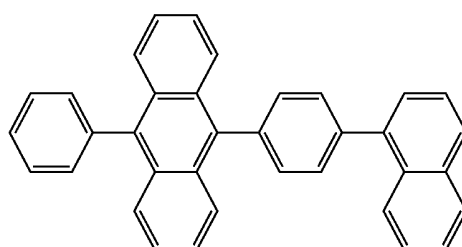
H5



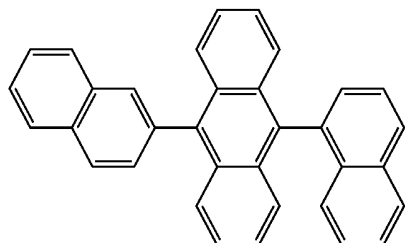
H6



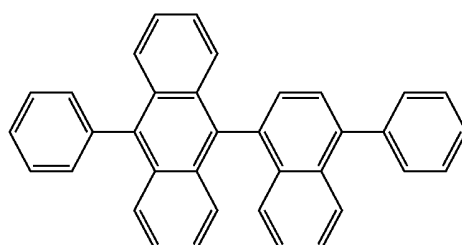
H1



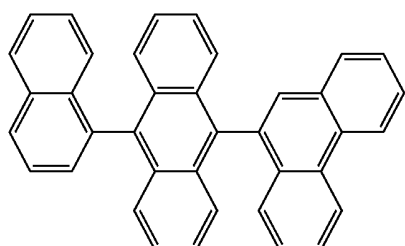
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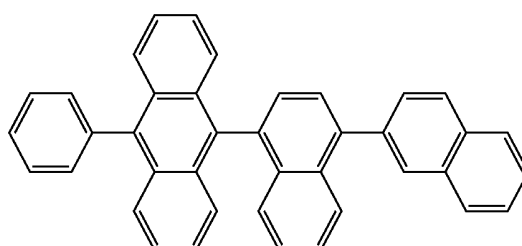
H2



H8

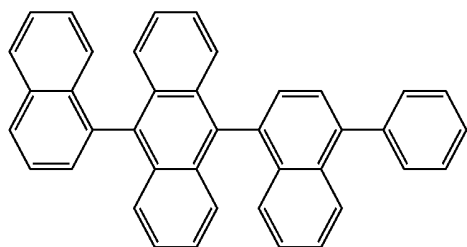


H3

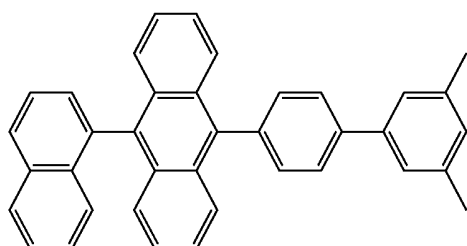


H9

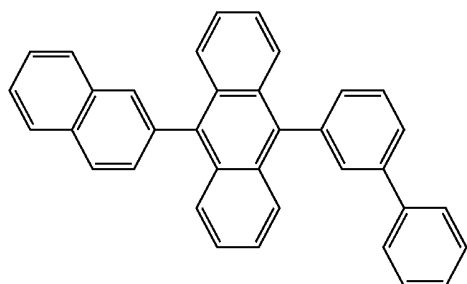
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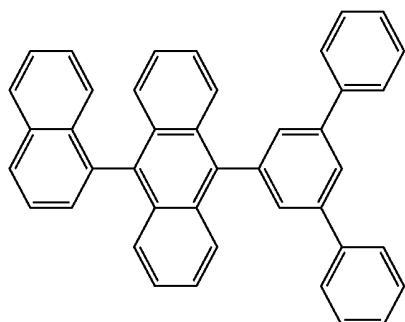
H10



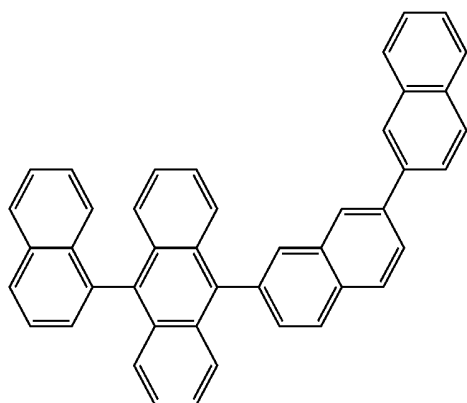
H11



H12

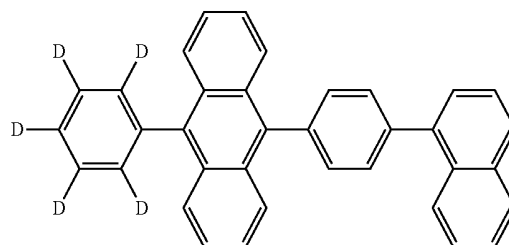


H13

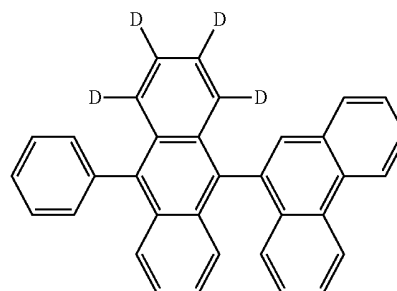


H14

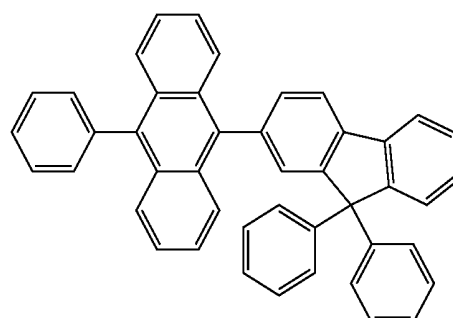
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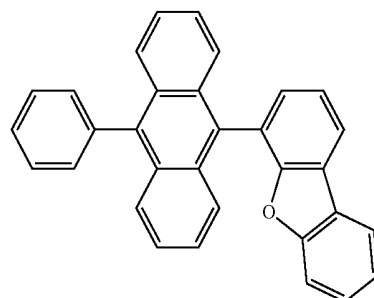
H15



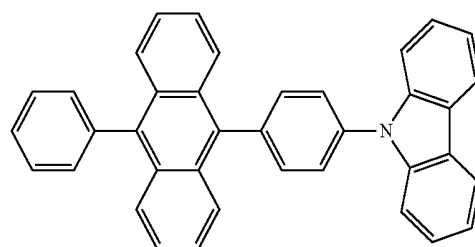
H16



H17

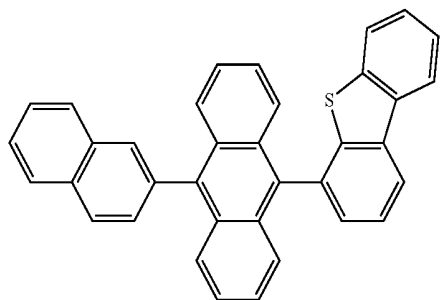


H18



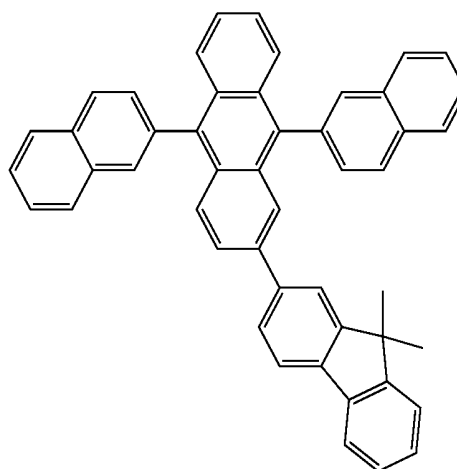
H19

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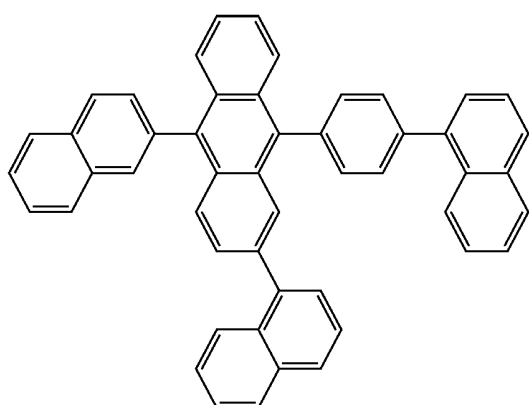


H20

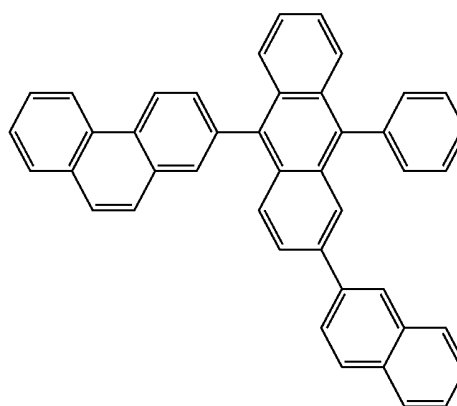
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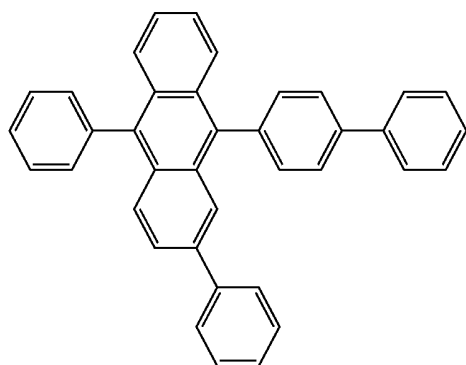
H23



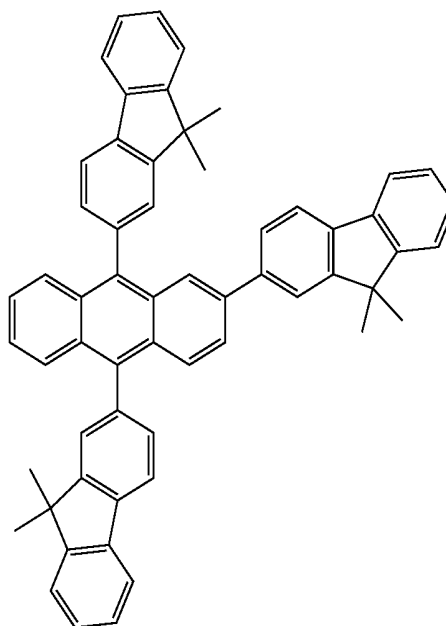
H21



H24

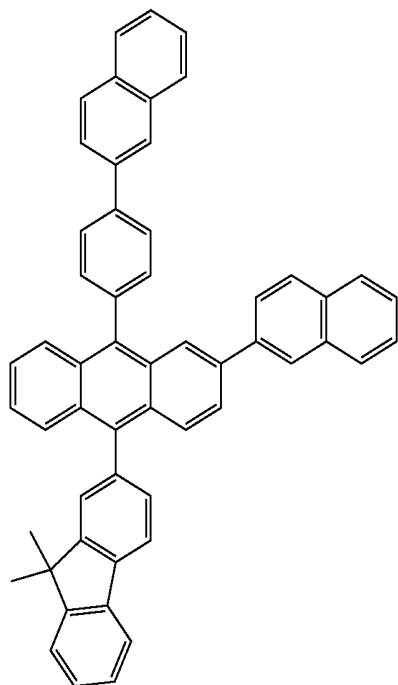


H22



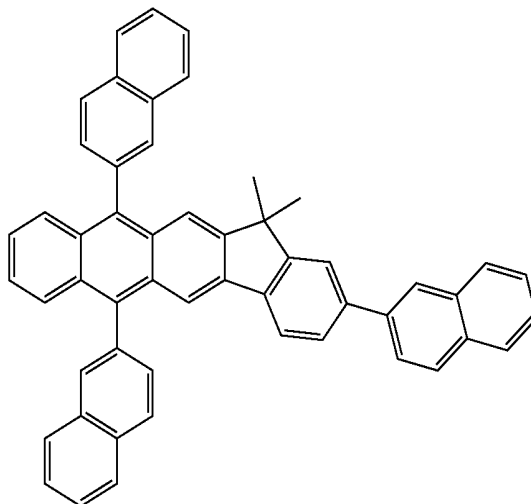
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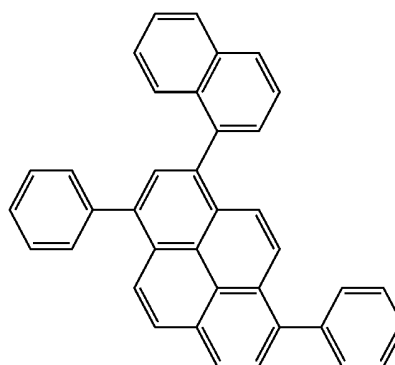
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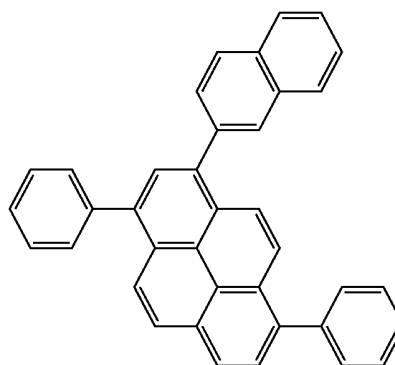
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H29

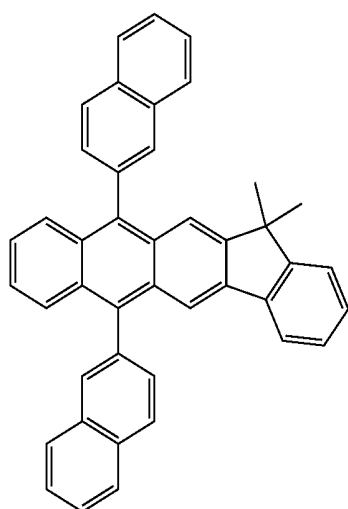


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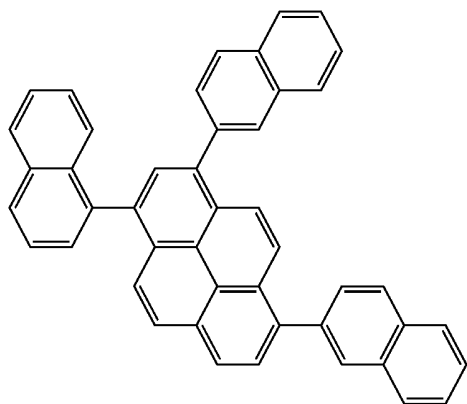
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H31

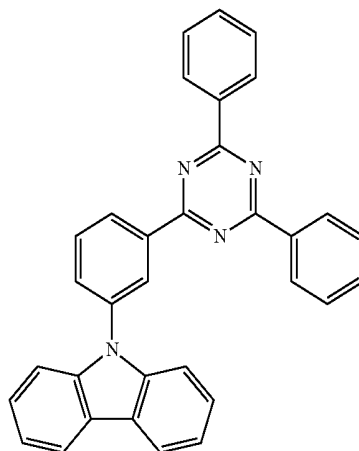


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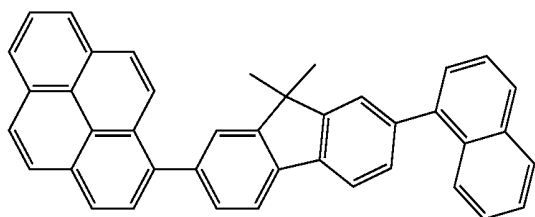
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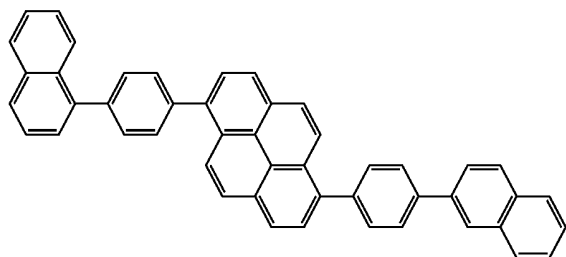


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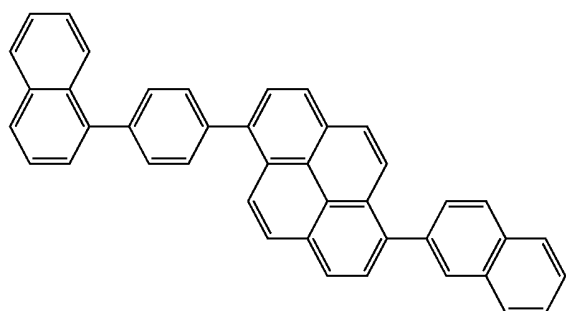
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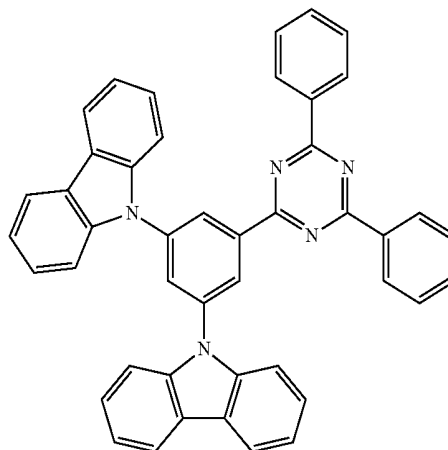
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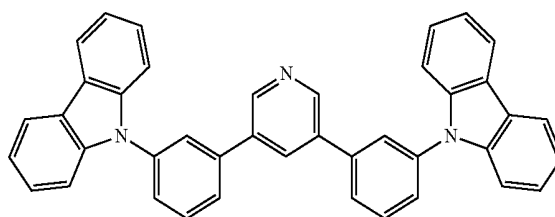
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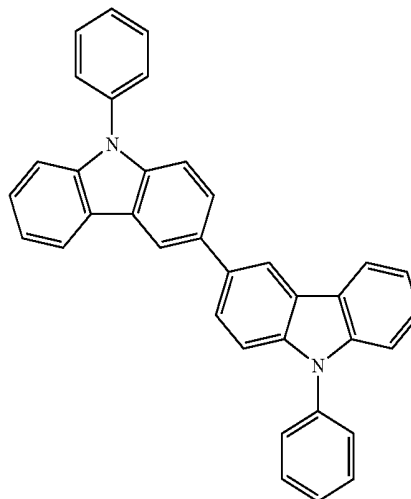
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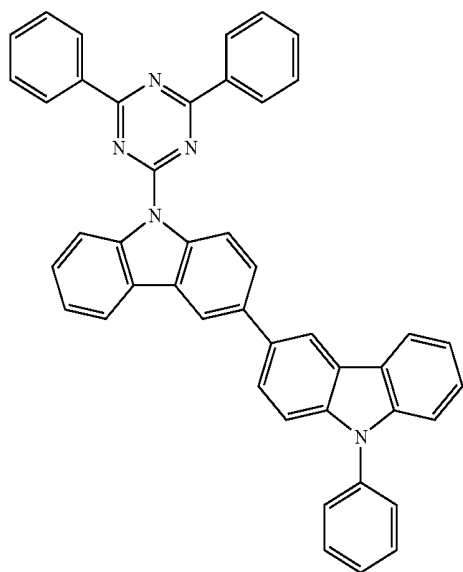
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H39

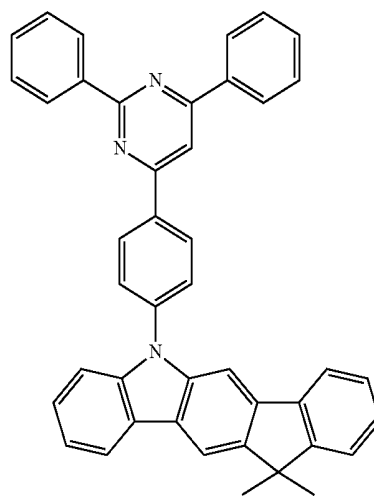


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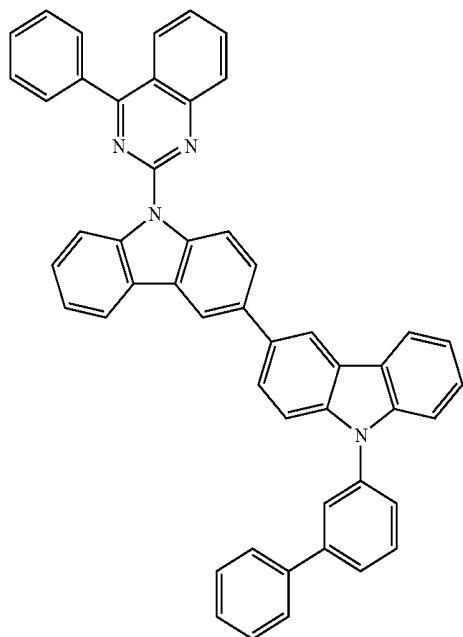
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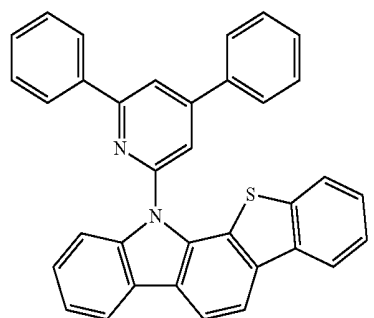


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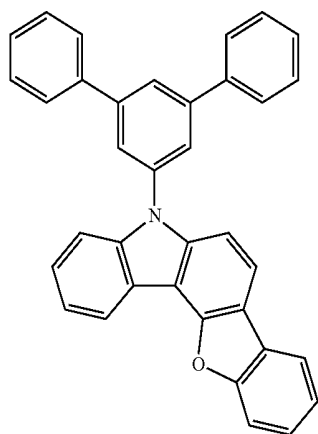
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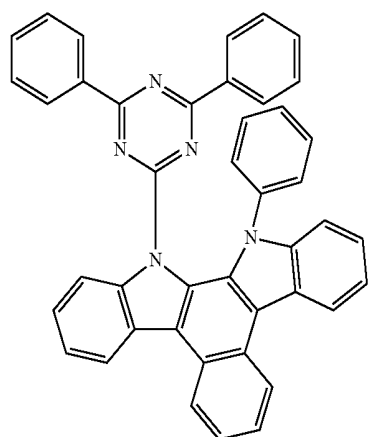
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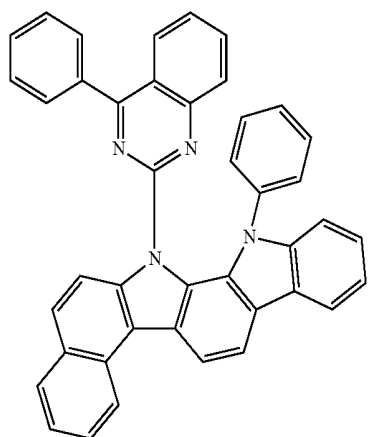
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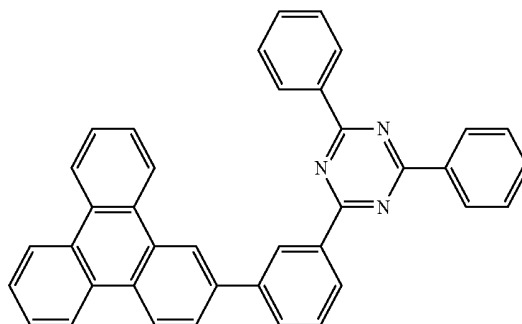


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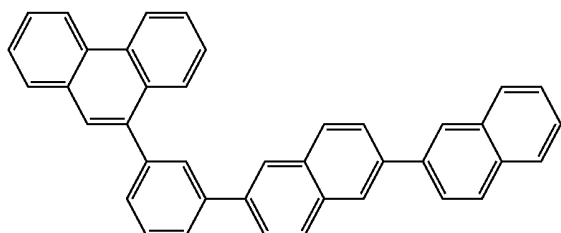


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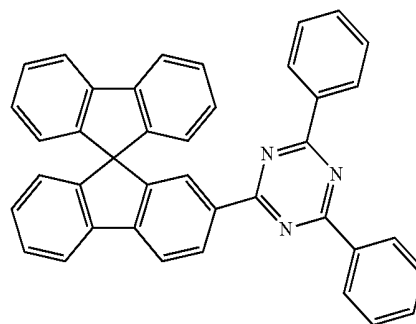
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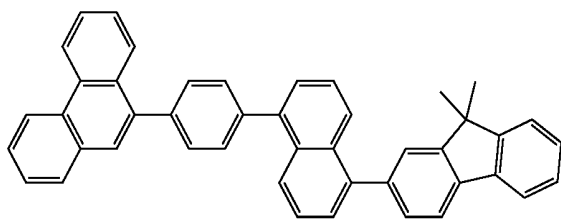
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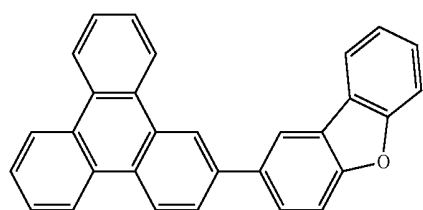
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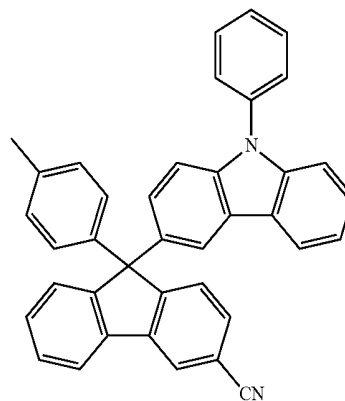
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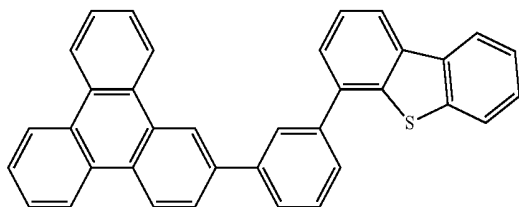
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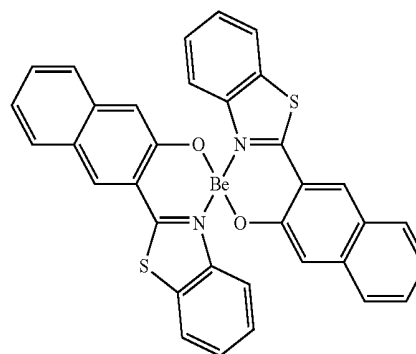
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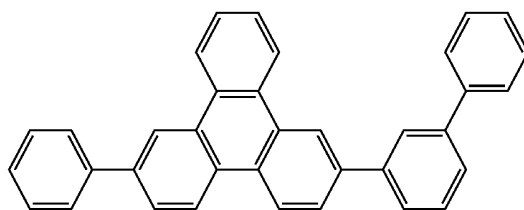
H54



H50



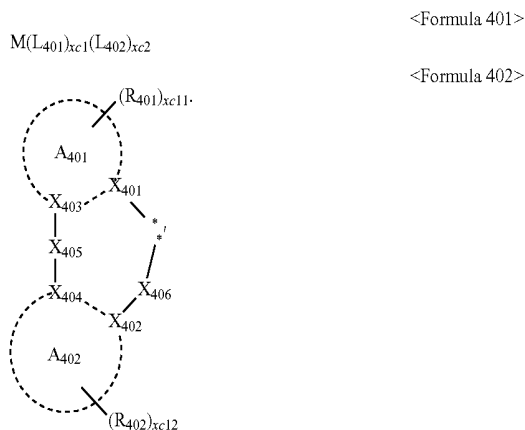
H55



H51

[0238] [Phosphorescent Dopant in Emission Layer of Organic Layer 150]

[0239] The phosphorescent dopant may include an organometallic complex represented by Formula 401:



[0240] In Formulae 401 and 402,

[0241] M may be selected from iridium (Ir), platinum (Pt), palladium (Pd), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), rhodium (Rh), and thulium (Tm),

[0242] L₄₀₁ may be selected from a ligand represented by Formula 402,

[0243] xc1 may be 1, 2, or 3, wherein, when xc1 is 2 or greater, at least two L₄₀₁(s) may be the same as or different from each other,

[0244] L₄₀₂ may be an organic ligand,

[0245] xc2 may be an integer of 0 to 4, wherein, when xc2 is 2 or greater, at least two L₄₀₂(s) may be the same as or different from each other,

[0246] X₄₀₁ to X₄₀₄ may each independently be N or C,

[0247] X₄₀₁ and X₄₀₃ may be linked via a single bond or a double bond, and X₄₀₂ and X₄₀₄ may be linked via a single bond or a double bond,

[0248] A₄₀₁ and A₄₀₂ may each independently be a C₅-C₆₀ carbocyclic group or a C₁-C₆₀ heterocyclic group,

[0249] X₄₀₅ may be a single bond, *—O—*, *—S—*, *—C(=O)—*, *—N(Q₄₁₁)—*, *—C(Q₄₁₁)(Q₄₁₂)—*, *—C(Q₄₁₁)=C(Q₄₁₂)—*, *—C(Q₄₁₁)=*, or *=C(Q₄₁₁)=* in which Q₄₁₁ and Q₄₁₂ may each independently be hydrogen, deuterium, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group,

[0250] X₄₀₆ may be a single bond, O, or S,

[0251] R₄₀₁ and R₄₀₂ may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C₁-C₂₀ alkyl group, a substituted or unsubstituted C₁-C₂₀ alkoxy group, a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(Q₄₀₁)(Q₄₀₂)(Q₄₀₃), —N(Q₄₀₁)(Q₄₀₂), —B(Q₄₀₁)(Q₄₀₂), —C(=O)(Q₄₀₁), —S(=O)₂(Q₄₀₁), and —P(=O)(Q₄₀₁)(Q₄₀₂) in which Q₄₀₁ to Q₄₀₃ may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a C₆-C₂₀ aryl group, and a C₁-C₂₀ heteroaryl group,

[0252] xc11 and xc12 may each independently be an integer of 0 to 10, and

[0253] * and *' in Formula 402 may be a binding site to M of Formula 401.

[0254] In an exemplary embodiment, A₄₀₁ and A₄₀₂ in Formula 402 may each independently be selected from a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, an indene group, a pyrrole group, a thiophene group, a furan group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a quinoxaline group, a quinazoline group, a carbazole group, a benzimidazole group, a benzofuran(benzofuran) group, a benzothiophene group, an isobenzothiophene group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a dibenzofuran group, and a dibenzothiophene group.

[0255] In an exemplary embodiment, in Formula 402, i) X₄₀₁ may be N, and X₄₀₂ may be C, or ii) X₄₀₁ and X₄₀₂ may be both N.

[0256] In an exemplary embodiment, in Formula 402, R₄₀₁ and R₄₀₂ may each independently be selected from:

[0257] 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, and a C₁-C₂₀ alkoxy group;

[0258] a C₁-C₂₀ alkyl group and a C₁-C₂₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a phenyl group, a naphthyl group, a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, and a norbornenyl group;

[0259] a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuran group, and a dibenzothiophenyl group;

[0260] a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuran 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, an adamantanyl group, a norbornanyl group, a norbornenyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazoliny group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

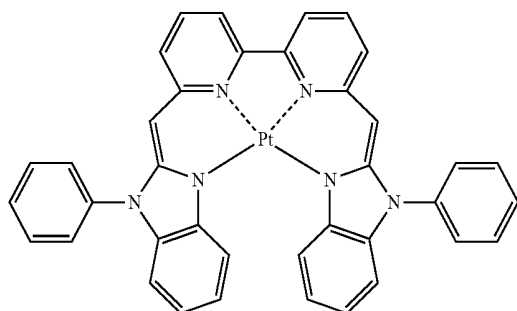
[0261] —Si(C₄₀₁)(Q₄₀₂)(Q₄₀₃), —N(Q₄₀₁)(Q₄₀₂), —B(Q₄₀₁)(Q₄₀₂), —C(=O)(Q₄₀₁), —S(=O)₂(Q₄₀₁), and —P(=O)(Q₄₀₁)(Q₄₀₂), and

[0262] Q₄₀₁ to Q₄₀₃ may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, and a naphthyl group, but the embodiments are not limited thereto.

[0263] In an exemplary embodiment, in Formula 401, when x1 is 2 or greater, two A₄₀₁(s) in at least two L₄₀₁(s) may be optionally linked to each other via X₄₀₇, which is a linking group. Alternatively, two A₄₀₂(S) in at least two L₄₀₁(s) may be optionally linked to each other via X₄₀₈, which is a linking group (see Compounds PD1 to PD4 and PD7). X₄₀₇ and X₄₀₈ may each independently be selected from a single bond, *—O—*, *—S—*, *—C(=O)—*, *—N(Q₄₁₃)*, *—C(Q₄₁₃)(Q₄₁₄)*, and *—C(Q₄₁₃)=C(Q₄₁₄)* (in which Q₄₁₃ and Q₄₁₄ may each independently be hydrogen, deuterium, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group), but the embodiments are not limited thereto.

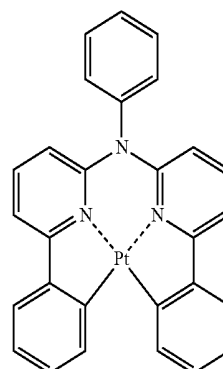
[0264] In Formula 401, L₄₀₂ may be selected from a monovalent, divalent, or trivalent organic ligand. For example, L₄₀₂ may be selected from a halogen ligand, diketone ligand (e.g., acetylacetonate), a carboxylic acid ligand (e.g., picolinate), —C(=O), an isonitrile ligand, —CN, and a phosphorus ligand (e.g., phosphine and phosphite), but the embodiments are not limited thereto.

[0265] In an exemplary embodiment, the phosphorescent dopant may be, for example, selected from Compounds PD1 to PD25, but the embodiments are not limited thereto:

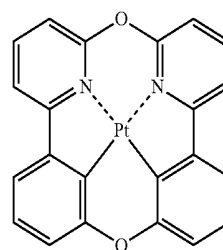


PD1

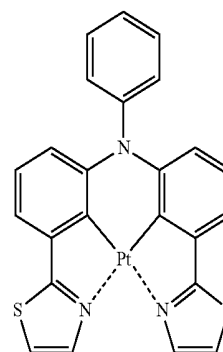
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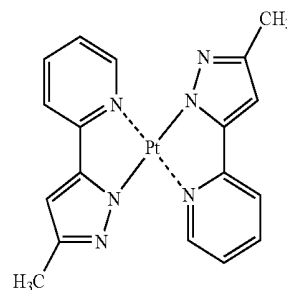
PD2



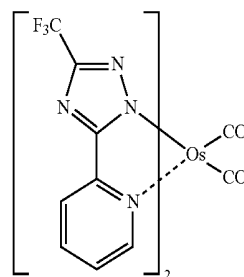
PD3



PD4

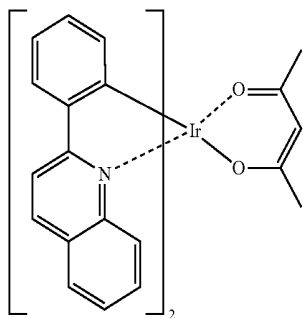
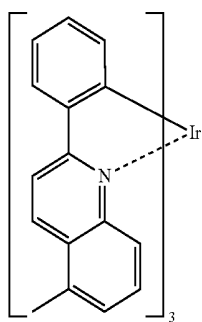
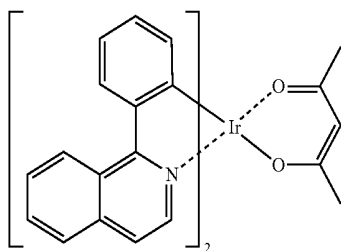
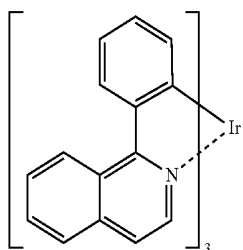
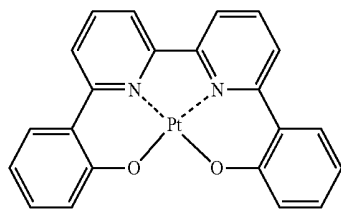


PD5



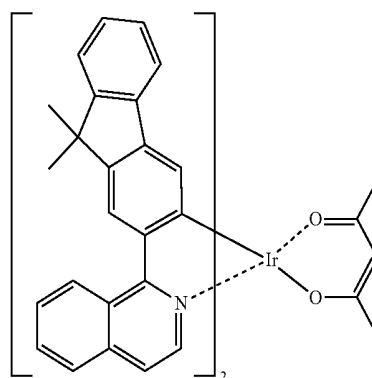
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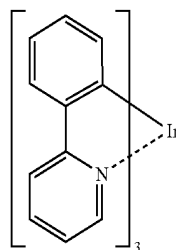


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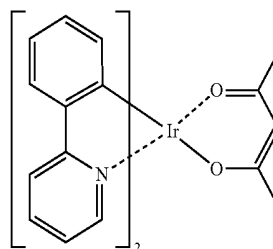
PD7



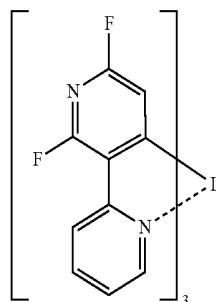
PD8



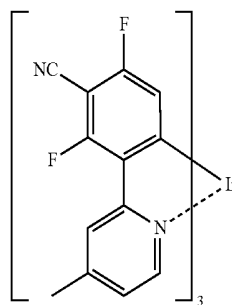
PD9



PD10



PD11



PD12

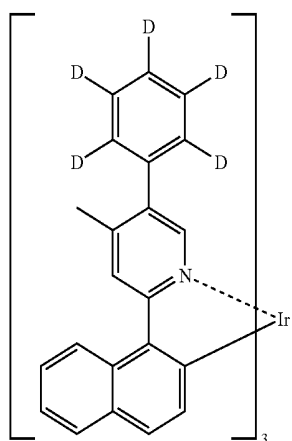
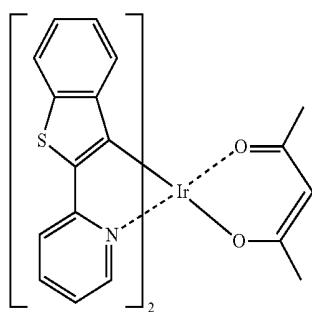
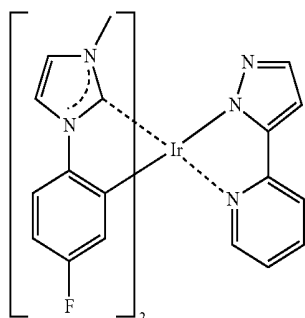
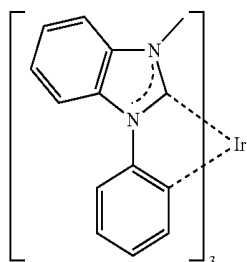
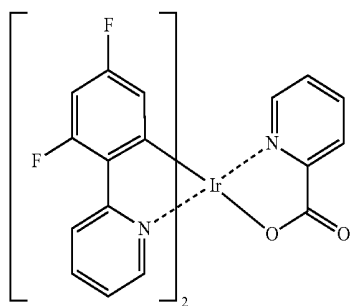
PD13

PD14

PD15

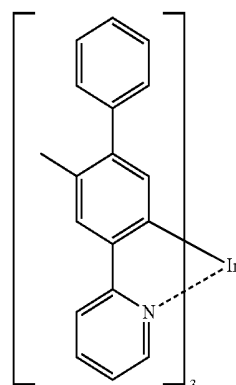
PD16

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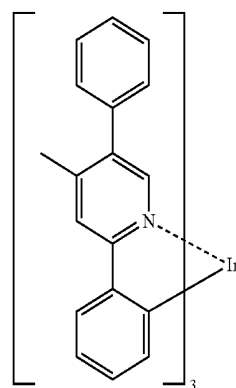
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PD17



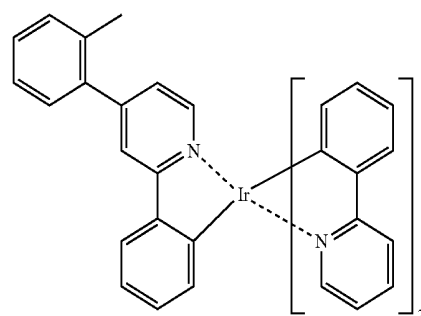
PD22

PD18



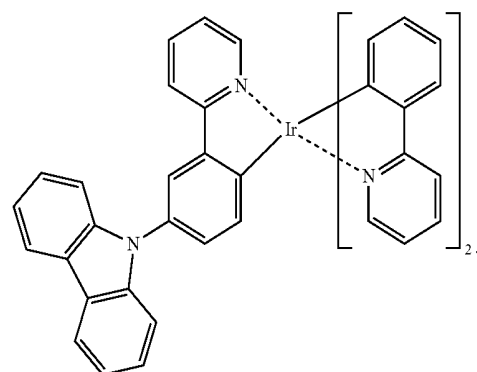
PD23

PD19



PD24

PD20



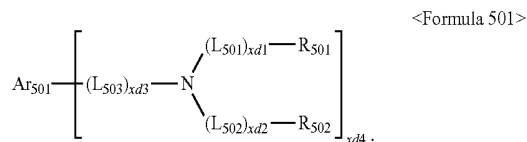
PD25

PD21

[Fluorescent Dopant in Emission Layer]

[0266] The fluorescent dopant may include an arylamine compound or a styramine compound.

[0267] The fluorescent dopant may include a compound represented by Formula 501:



[0268] In Formula 501,

[0269] Ar_{501} may be a substituted or unsubstituted C_2 - C_{60} carbocyclic group or a substituted or unsubstituted C_1 - C_{60} heterocyclic group,

[0270] L_{501} to L_{503} may each independently be selected from a substituted or unsubstituted C_3 - C_{10} cycloalkylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3 - C_{10} cycloalkenylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6 - C_{60} arylene group, a substituted or unsubstituted C_1 - C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0271] $xd1$ to $xd3$ may each independently be an integer of 0 to 3,

[0272] R_{501} and R_{502} may each independently be selected from a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6 - C_{60} aryl group, a substituted or unsubstituted C_6 - C_{60} aryloxy group, a substituted or unsubstituted C_6 - C_{60} aryloxy group, a substituted or unsubstituted C_6 - C_{60} arylthio group, a substituted or unsubstituted C_1 - C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, and

[0273] $xd4$ may be an integer of 1 to 6.

[0274] In an exemplary embodiment, in Formula 501, Ar_{501} may be selected from:

[0275] a naphthalene group, a heptalene 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, and an indenophenanthrene group; and

[0276] a naphthalene group, a heptalene 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, and an indenophenanthrene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0277] In an exemplary embodiment, in Formula 501, L_{501} to L_{503} may each independently be selected from:

[0278] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthre-

nylene group, an anthracenylylene group, a fluoranthenylylene group, a triphenylylene group, a pyrenylene group, a chrysenylene group, a perylynylene group, a pentaphenylylene group, a hexacenylylene group, a pentacenylylene group, a thiophenylylene group, a furanylylene group, a carbazolylylene group, an indolylylene group, an isoindolylylene group, a benzofuranylylene group, a benzothiophenylylene group, a dibenzofuranylylene group, a dibenzothiophenylylene group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, and a pyridinylylene group; and

[0279] a phenylene group, a naphthylene group, a fluorenylylene group, a spiro-bifluorenylylene group, a benzofluorenylylene group, a dibenzofluorenylylene group, a phenanthrenylylene group, an anthracenylylene group, a fluoranthenylylene group, a triphenylylylene group, a pyrenylene group, a chrysenylene group, a perylynylene group, a pentaphenylylene group, a hexacenylylene group, a pentacenylylene group, a thiophenylylene group, a furanylylene group, a carbazolylylene group, an indolylylene group, an isoindolylylene group, a benzofuranylylene group, a benzothiophenylylene group, a dibenzofuranylylene group, a dibenzothiophenylylene group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, and a pyridinylylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylylyl group, a pyrenyl group, a chrysenyl group, a perylynyl group, a pentaphenyl group, a hexacenylyl group, a pentacenylyl group, a thiophenyl group, a furanylyl group, a carbazolylyl group, an indolylyl group, a benzofuranylyl group, a benzothiophenyl group, a dibenzofuranylyl group, a dibenzothiophenyl group, a benzocarbazolylyl group, a dibenzocarbazolylyl group, a dibenzosilolylyl group, and a pyridinylyl group.

[0280] In an exemplary embodiment, in Formula 501, R_{501} and R_{502} may each independently be selected from:

[0281] 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 triphenylylyl group, a pyrenyl group, a chrysenyl group, a perylynyl group, a pentaphenyl group, a hexacenylyl group, a pentacenylyl group, a thiophenyl group, a furanylyl group, a carbazolylyl group, an indolylyl group, an isoindolylyl group, a benzofuranylyl group, a benzothiophenyl group, a dibenzofuranylyl group, a dibenzothiophenyl group, a benzocarbazolylyl group, a dibenzocarbazolylyl group, a dibenzosilolylyl group, and a pyridinylyl group; and

[0282] 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 triphenylylyl group, a pyrenyl group, a chrysenyl group, a perylynyl group, a pentaphenyl group, a hexacenylyl group, a pentacenylyl group, a thiophenyl group, a furanylyl group, a carbazolylyl group, an indolylyl group, an isoindolylyl group, a benzofuranylyl group, a benzothiophenyl group, a dibenzofuranylyl group, a dibenzothiophenyl group, a benzocarbazolylyl group, a dibenzocarbazolylyl group, a dibenzosilolylyl group, and a pyridinylyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an

amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a 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, and $-Si(Q_{31})(Q_{32})(Q_{33})$, and

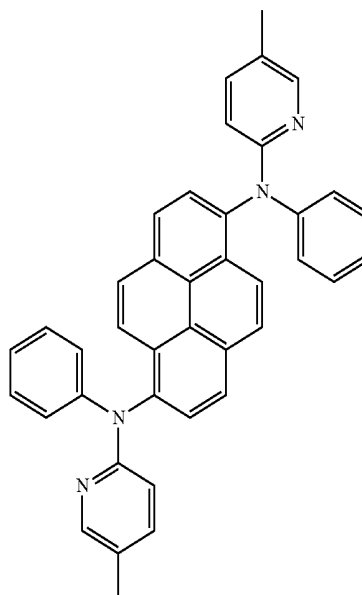
[0283] Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0284] In an exemplary embodiment, in Formula 501, xd4 may be 2, but the embodiments are not limited thereto.

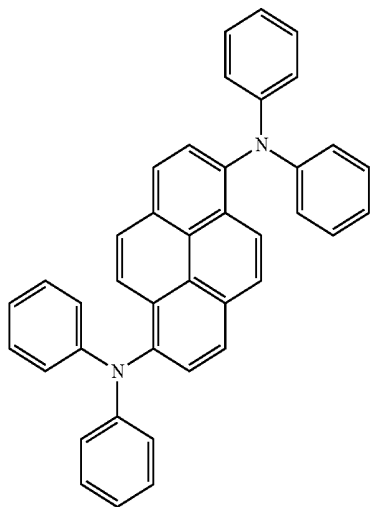
[0285] In an exemplary embodiment, the fluorescent dopant may be selected from Compounds FD1 to FD22:

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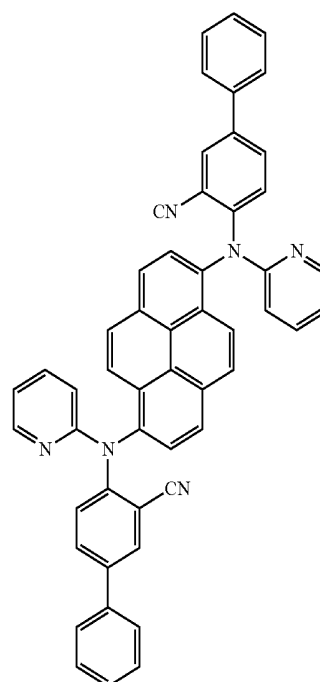
FD3



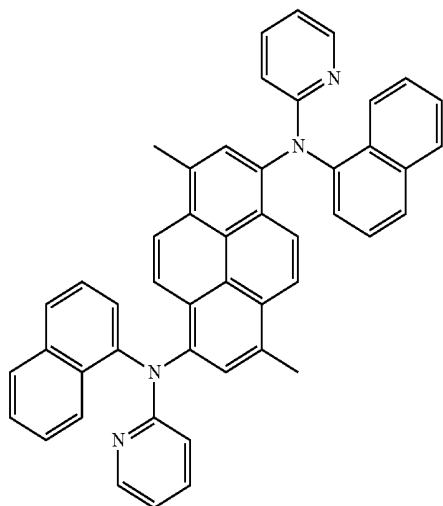
FD1



FD4

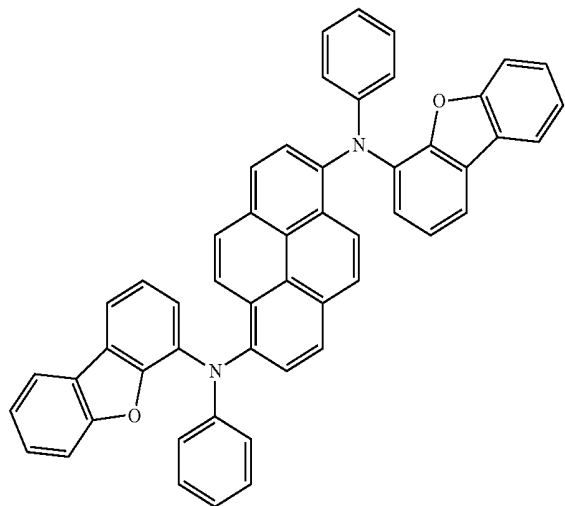


FD2



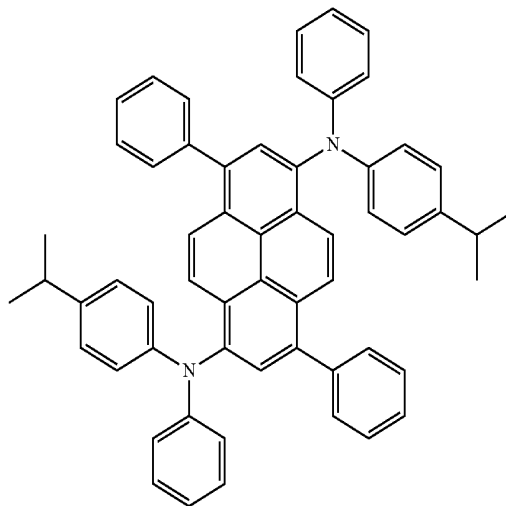
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FD5

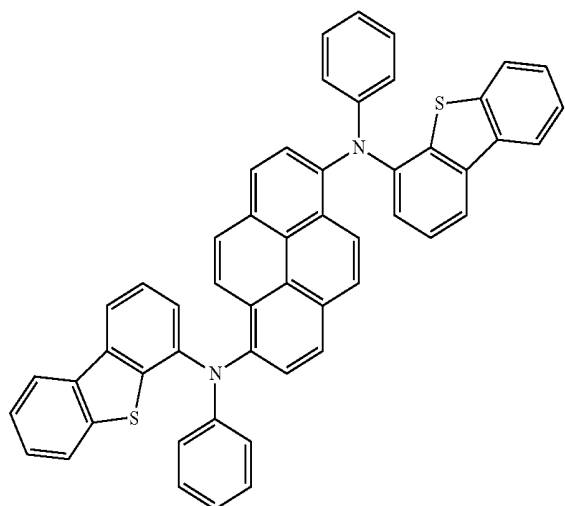


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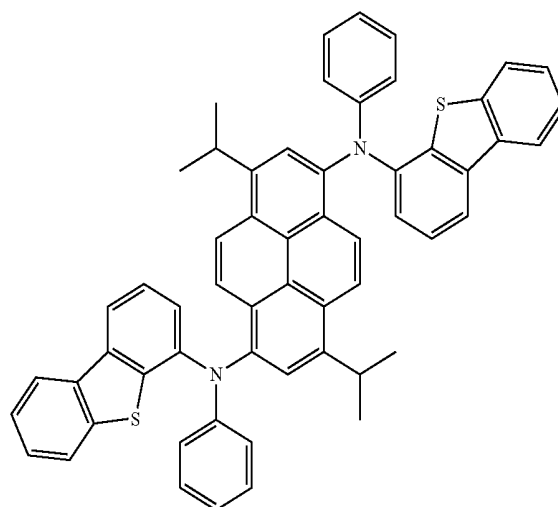
FD8



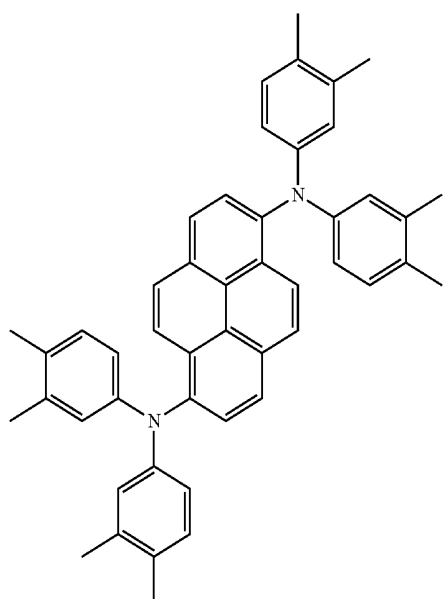
FD6



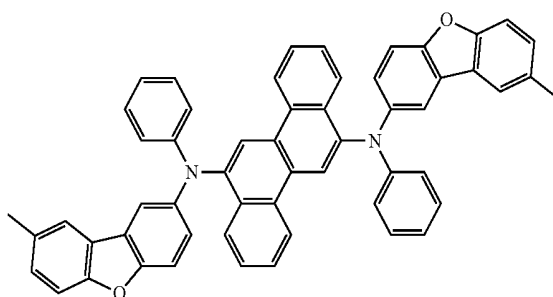
FD9



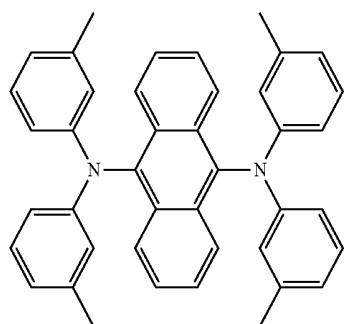
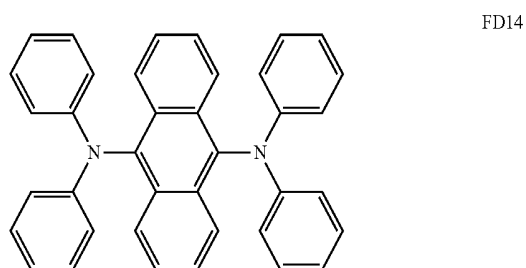
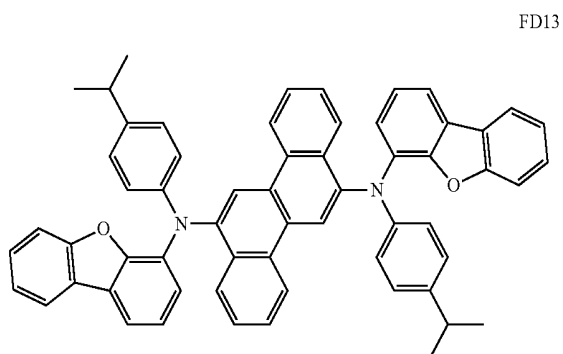
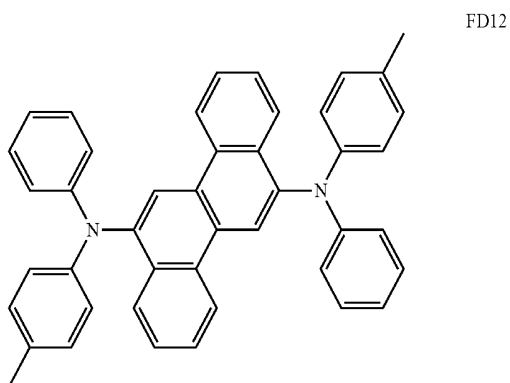
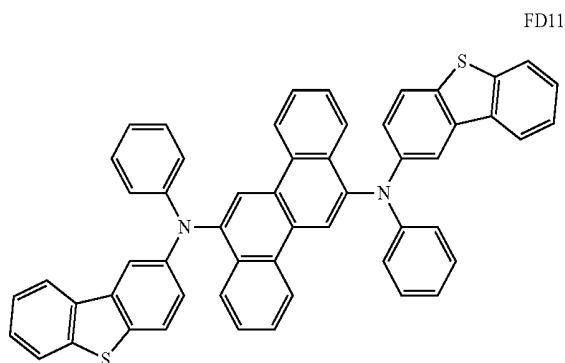
FD7



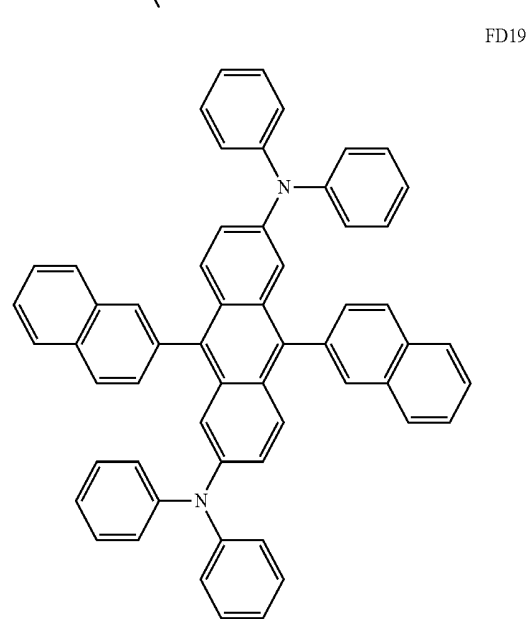
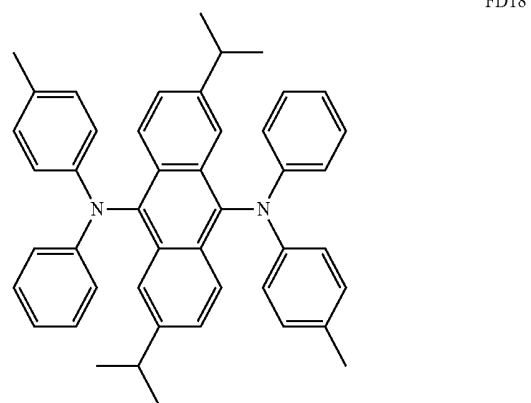
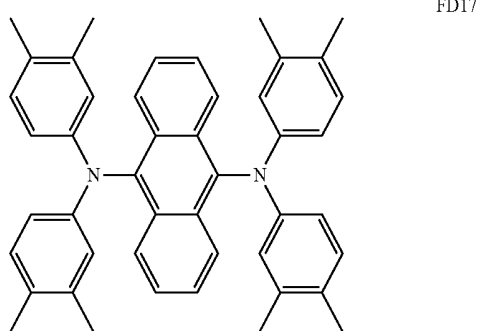
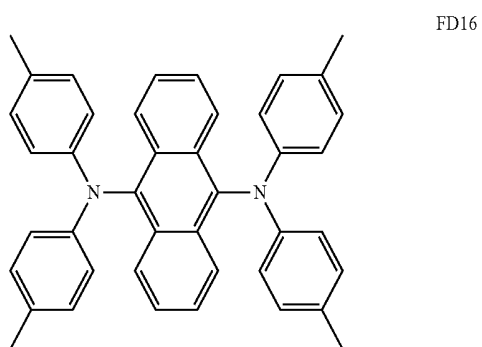
FD10



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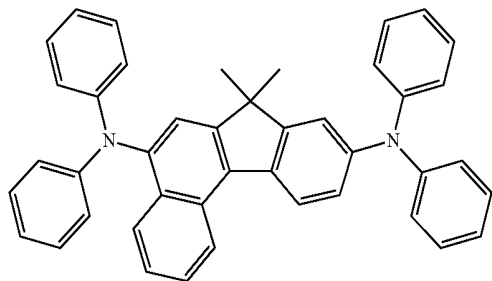


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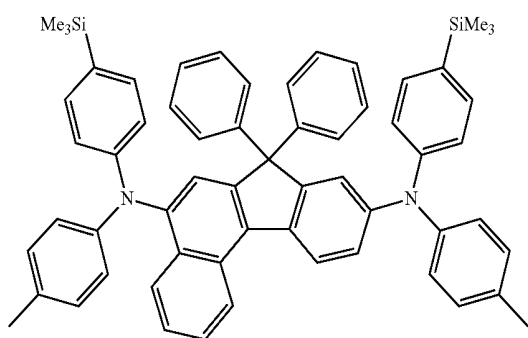


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FD20

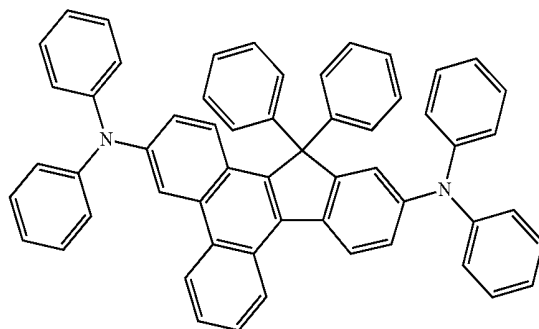


FD21

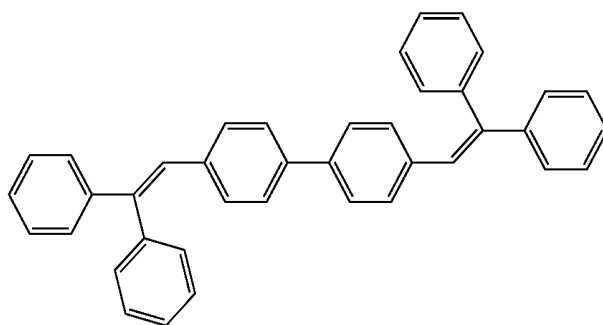


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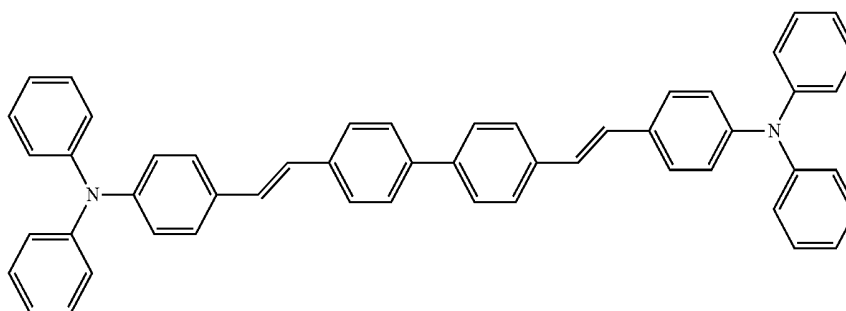
FD22



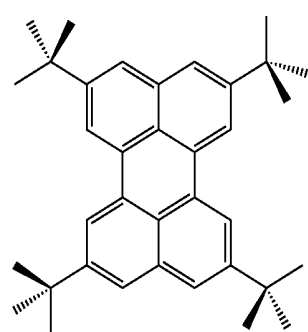
[0286] In an exemplary embodiment, the fluorescent dopant may be selected from the compounds illustrated below, but the embodiments are not limited thereto:



DPVBi

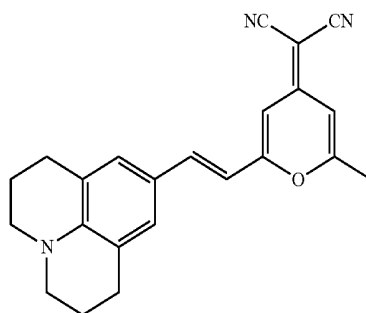


DPAVBi

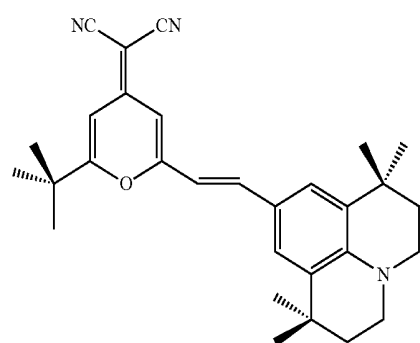


TBPc

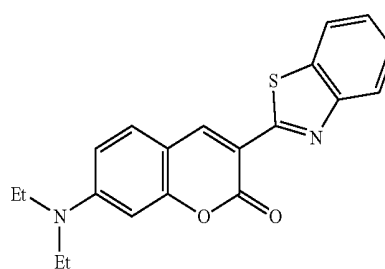
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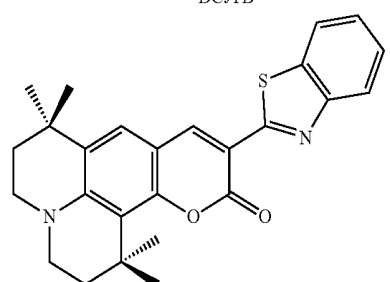
DCM



DCJTb



Coumarin 6



C545T

[Electron Transport Region in Organic Layer 150]

[0287] The electron transport region may have i) a single-layered structure 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.

[0288] The electron transport region may include at least one layer selected from a buffer layer, a hole blocking layer, an electron control layer, an electron transport layer, and an electron injection layer, but the embodiments are not limited thereto.

[0289] 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. For each structure, the layers may be sequentially stacked on the emission layer in this stated order, but the embodiments are not limited thereto.

[0290] The electron transport region (for example, a buffer layer, a hole blocking layer, an electron control layer, or an

electron transport layer in the electron transport region) may include a metal-free compound containing at least one π electron-depleted nitrogen-containing ring.

[0291] The “ π electron-depleted nitrogen-containing ring” indicates a C_1 - C_{60} heterocyclic group having at least one $*-N=*$ moiety as a ring-forming moiety.

[0292] 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, or iii) a heteropolycyclic group in which at least one of 5-membered to 7-membered heteromonocyclic groups, each having at least one $*-N=*$ moiety, is condensed with at least one C_5 - C_{60} carbocyclic group.

[0293] Examples of the π electron-depleted nitrogen-containing ring include an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, a naphthyridine

group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, a phenanthroline group, a phenazine group, a benzimidazole group, an isobenzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a thiadiazol group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group, but the embodiments are not limited thereto.

[0294] For example, the electron transport region may include a compound represented by Formula 601.



[0295] In Formula 601,

[0296] Ar_{601} may be a substituted or unsubstituted $\text{C}_5\text{-C}_{60}$ carbocyclic group or a substituted or unsubstituted $\text{C}_1\text{-C}_{60}$ heterocyclic group,

[0297] $\text{xe}11$ may be 1, 2, or 3,

[0298] L_{601} may be selected from a substituted or unsubstituted $\text{C}_3\text{-C}_{10}$ cycloalkylene group, a substituted or unsubstituted $\text{C}_1\text{-C}_{10}$ heterocycloalkylene group, a substituted or unsubstituted $\text{C}_3\text{-C}_{10}$ cycloalkenylene group, a substituted or unsubstituted $\text{C}_1\text{-C}_{10}$ heterocycloalkenylene group, a substituted or unsubstituted $\text{C}_6\text{-C}_{60}$ arylene group, a substituted or unsubstituted $\text{C}_1\text{-C}_{60}$ heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0299] $\text{xe}1$ may be an integer of 0 to 5,

[0300] R_{601} may be selected from a substituted or unsubstituted $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a substituted or unsubstituted $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, a substituted or unsubstituted $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a substituted or unsubstituted $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, a substituted or unsubstituted $\text{C}_6\text{-C}_{60}$ aryl group, a substituted or unsubstituted $\text{C}_6\text{-C}_{60}$ aryloxy group, a substituted or unsubstituted $\text{C}_6\text{-C}_{60}$ arylthio group, a substituted or unsubstituted $\text{C}_1\text{-C}_{60}$ heteroaryl group, a substituted or unsubstituted non-valent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, $-\text{Si}(\text{Q}_{601})(\text{Q}_{602})(\text{Q}_{603})$, $-\text{C}(=\text{O})(\text{Q}_{601})$, $-\text{S}(=\text{O})_2(\text{Q}_{601})$, and $-\text{P}(=\text{O})(\text{Q}_{601})(\text{Q}_{602})$,

[0301] Q_{601} to Q_{603} may each independently be a $\text{C}_1\text{-C}_{10}$ alkyl group, a $\text{C}_1\text{-C}_{10}$ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group, and

[0302] $\text{xe}21$ may be an integer of 1 to 5.

[0303] In an exemplary embodiment, at least one of Ar_{601} (s) in the number of $\text{xe}11$ and/or at least one of R_{601} (s) in the number of $\text{xe}21$ may include the π electron-depleted nitrogen-containing ring.

[0304] In an exemplary embodiment, ring Ar_{601} in Formula 601 may be selected from:

[0305] 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, naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, 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, thiadiazol group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group;

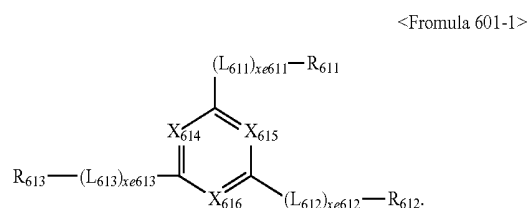
[0306] a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene 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, naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, 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, thiadiazol group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group, each substituted with at least one selected from deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a $\text{C}_1\text{-C}_{20}$ alkyl group, a $\text{C}_1\text{-C}_{20}$ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, $-\text{S}(=\text{O})_2(\text{Q}_{31})$, and $-\text{P}(=\text{O})(\text{Q}_{31})(\text{Q}_{32})$,

[0307] Q_{31} to Q_{33} may each independently be selected from a $\text{C}_1\text{-C}_{10}$ alkyl group, a $\text{C}_1\text{-C}_{10}$ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0308] In Formula 601, when $\text{xe}11$ is 2 or greater, at least two Ar_{601} (s) may be linked via a single bond.

[0309] In an exemplary embodiment, in Formula 601, Ar_{601} may be an anthracene group.

[0310] In an exemplary embodiment, the compound represented by Formula 601 may be represented by Formula 601-1:



[0311] In Formula 601-1,

[0312] X_{614} may be N or C(R_{614}), X_{615} may be N or C(R_{615}), X_{616} may be N or C(R_{616}), and at least one selected from X_{614} to X_{616} may be N,

[0313] L_{611} to L_{613} may each independently be the same as L_{601} ,

[0314] xe611 to xe613 may each independently be the same as xe1,

[0315] R_{611} to R_{613} may each independently be the same as R_{601} , and

[0316] R_{614} to R_{616} 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 phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0317] In an exemplary embodiment, in Formulae 601 and 601-1, L_{601} and L_{611} to L_{613} may each independently be selected from:

[0318] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylylene group, a fluoranthenylylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylylene group, a hexacenylylene group, a pentacenylylene group, a thiophenylylene group, a furanylylene group, a carbazolylylene group, an indolylylene group, an isoindolylylene group, a benzofuranylylene group, a benzothiophenylylene group, a dibenzofuranylylene group, a dibenzothiophenylylene group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, a pyridinylylene group, an imidazolylylene group, a pyrazolylylene group, a thiazolylylene group, an isothiazolylylene group, an oxazolylylene group, an isoxazolylylene group, a thiadiazolylylene group, an oxadiazolylylene group, a pyrazinylylene group, a pyrimidinylylene group, a pyridazinylylene group, a triazinylylene group, a quinolinylylene group, an isoquinolinylylene group, a benzoquinolinylylene group, a phthalazinylylene group, a naphthyridinylylene group, a quinoxalinylylene group, a quinazolinylylene group, a cinnolinylylene group, a phenanthridinylylene group, an acridinylylene group, a phenanthrolinylylene group, a phenazinylylene group, a benzimidazolylylene group, an isobenzothiazolylylene group, a benzoxazolylylene group, a triazolylylene group, a tetrazolylylene group, an imidazopyridinylylene group, an imidazopyrimidinylylene group, and an azacarbazolylylene group; and

[0319] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylylene group, a fluoranthenylylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylylene group, a hexacenylylene group, a pentacenylylene group, a thiophenylylene group, a furanylylene group, a carbazolylylene group, an indolylylene group, an isoindolylylene group, a benzofuranylylene group, a benzothiophenylylene group, a dibenzofuranylylene group, a dibenzothiophenylylene group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, a pyridinylylene group, an imidazolylylene group, a pyrazolylylene group, a thiazolylylene group, an isothiazolylylene group, an oxazolylylene group, an isoxazolylylene group, a thiadiazolylylene group, an oxadiazolylylene group, a pyrazinylylene group, a pyrimidinylylene group, a pyridazinylylene group, a triazinylylene group, a quinolinylylene group, an isoquinolinylylene group, a benzoquinolinylylene group, a phthalazinylylene group, a naphthyridinylylene group, a quinoxalinylylene group, a quinazolinylylene group, a cinnolinylylene group, a phenanthridinylylene group, an acridinylylene group, a phenanthrolinylylene group, a phenazinylylene group, a benzimidazolylylene group, an isobenzothiazolylylene group, a benzoxazolylylene group, a triazolylylene group, a tetrazolylylene group, an imidazopyridinylylene group, an imidazopyrimidinylylene group, and an azacarbazolylylene group, but the embodiments are not limited thereto.

linylene group, a phenanthridinylylene group, an acridinylylene group, a phenanthrolinylylene group, a phenazinylylene group, a benzimidazolylylene group, an isobenzothiazolylylene group, a benzoxazolylylene group, an isobenzoxazolylylene group, a triazolylylene group, a tetrazolylylene group, an imidazopyridinylylene group, an imidazopyrimidinylylene group, and an azacarbazolylylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenylyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenylyl group, a pentacenylyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinylyl group, an isoquinolinylyl group, a benzoquinolinylyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinylyl group, a quinazolinylyl group, a cinnolinylyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, but the embodiments are not limited thereto.

[0320] In an exemplary embodiment, in Formulae 601 and 601-1, xe1 and xe611 to xe613 may each independently be 0, 1, or 2.

[0321] In an exemplary embodiment, in Formulae 601 and 601-1, R_{601} and R_{611} to R_{613} may each independently be selected from:

[0322] 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 fluoranthenylyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenylyl group, a pentacenylyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinylyl group, an isoquinolinylyl group, a benzoquinolinylyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinylyl group, a quinazolinylyl group, a cinnolinylyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl

group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group;

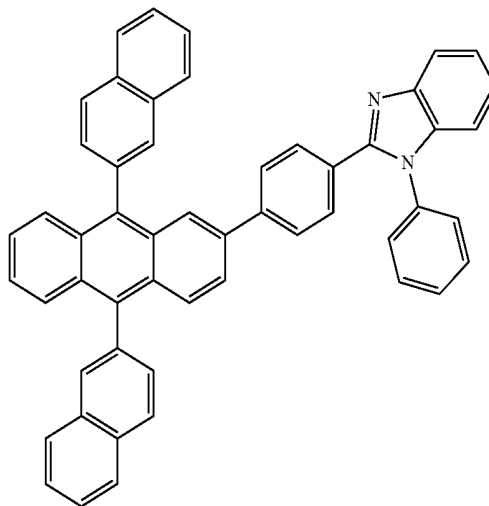
[0323] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexaceny group, a pentaceny group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexaceny group, a pentaceny group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group; and

[0324] —S(=O)₂(Q₆₀₁) and —P(=O)(Q₆₀₁)(Q₆₀₂), and

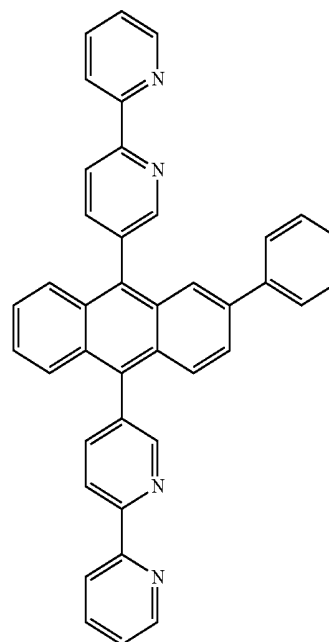
[0325] Q₆₀₁ and Q₆₀₂ may each independently be the same as defined herein.

[0326] The electron transport region may include at least one compound selected from Compounds ET1 to ET36, but the embodiments are not limited thereto:

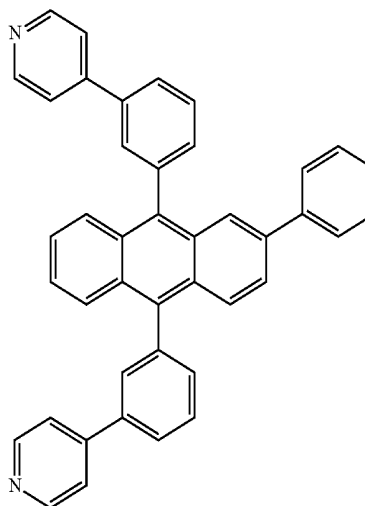
ET1



ET2

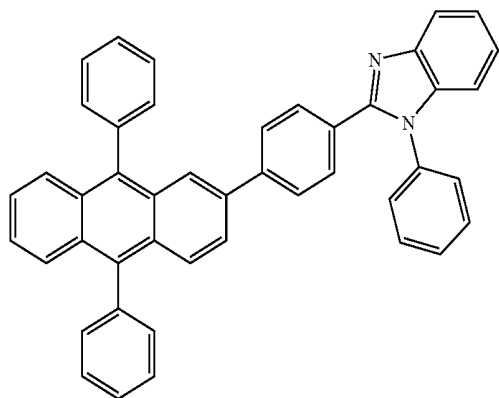


ET3



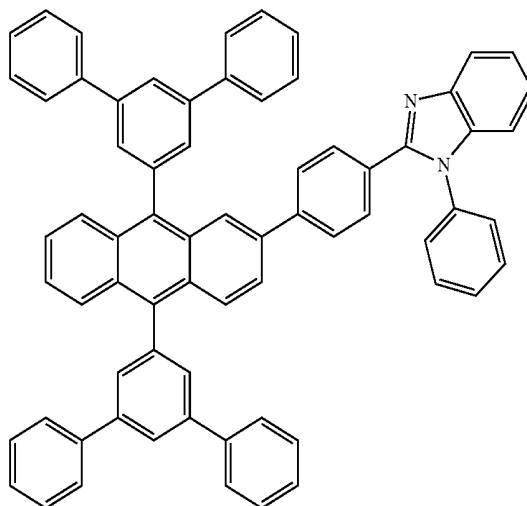
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ET4

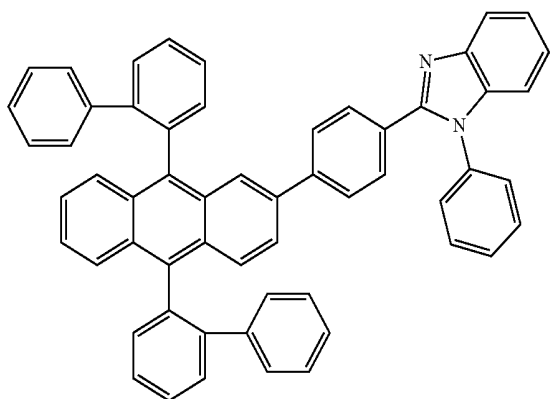


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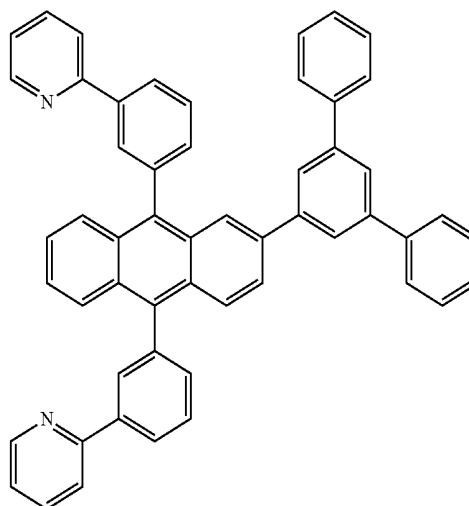
ET7



ET5

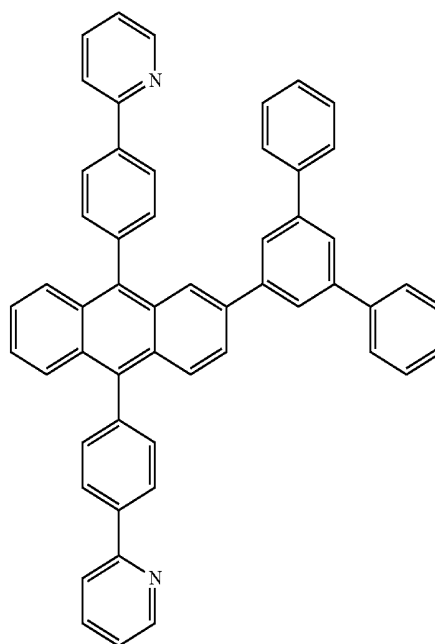
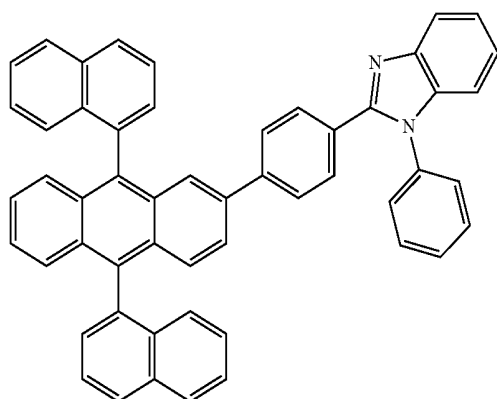


ET8

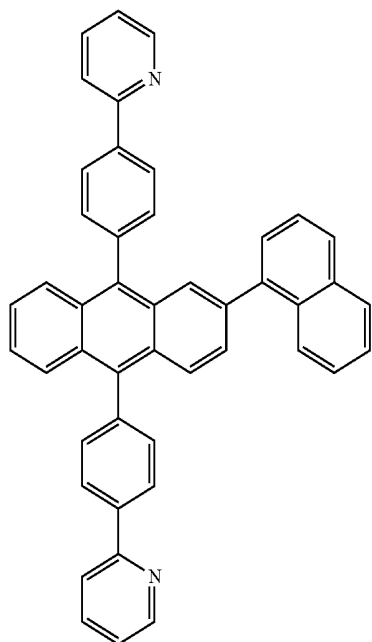


ET9

ET6

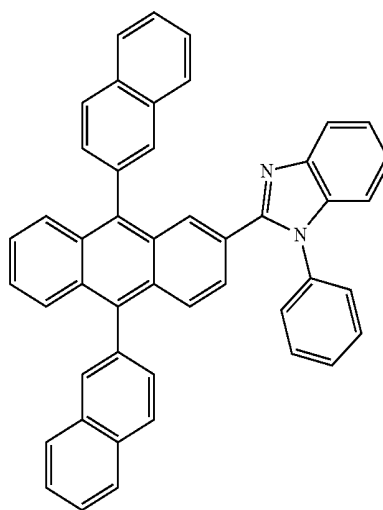


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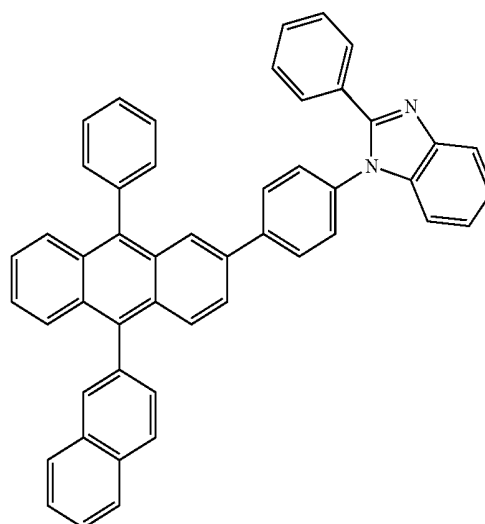
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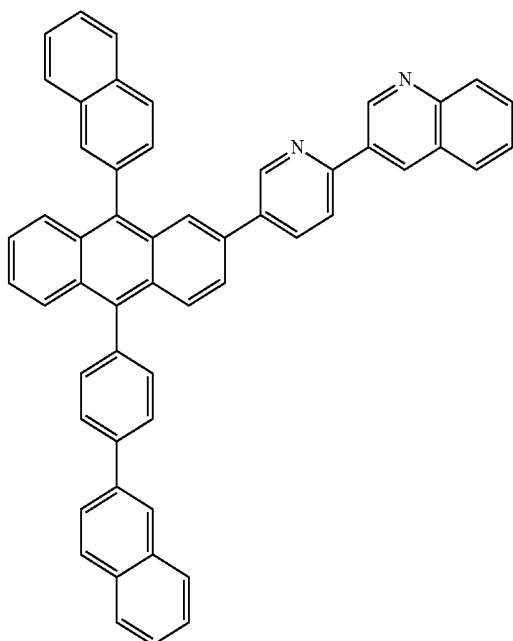


ET12

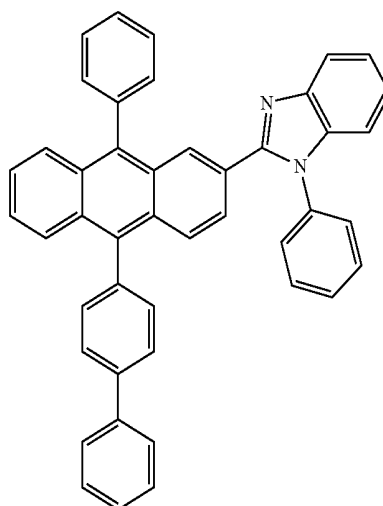
ET13



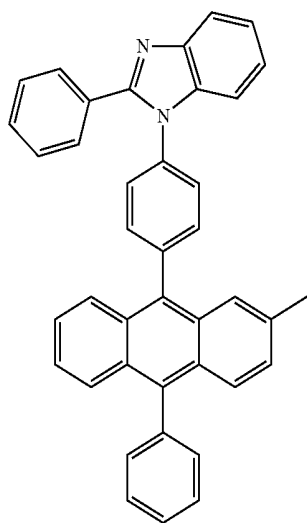
ET11



ET14

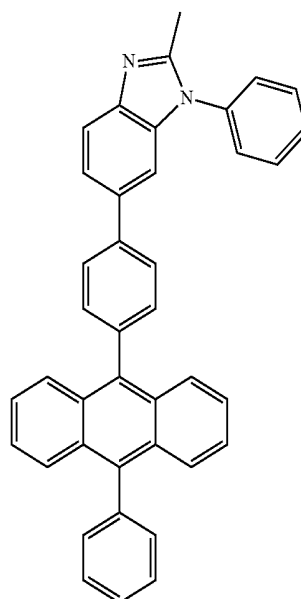


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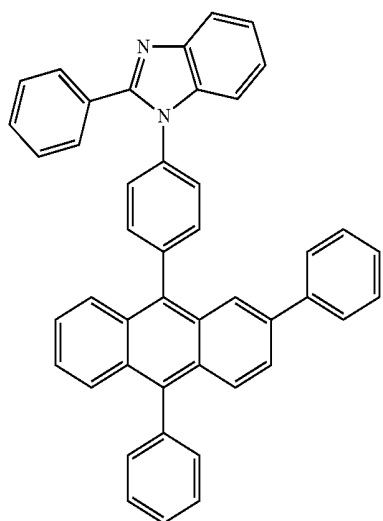
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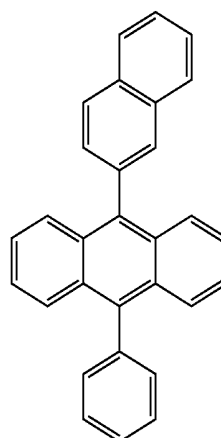


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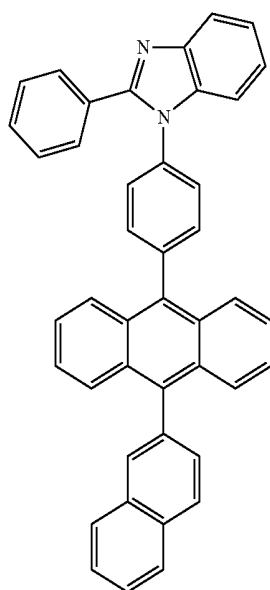
ET18



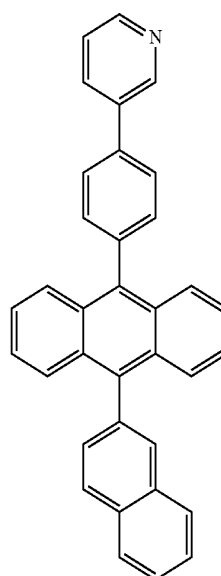
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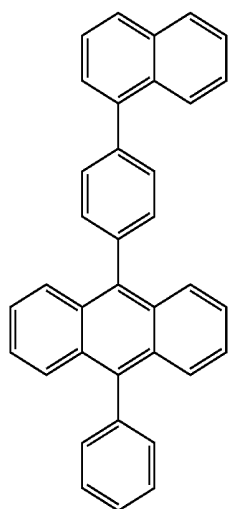
ET19



ET20

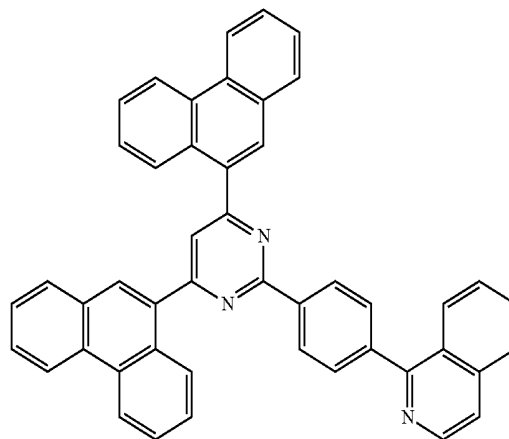


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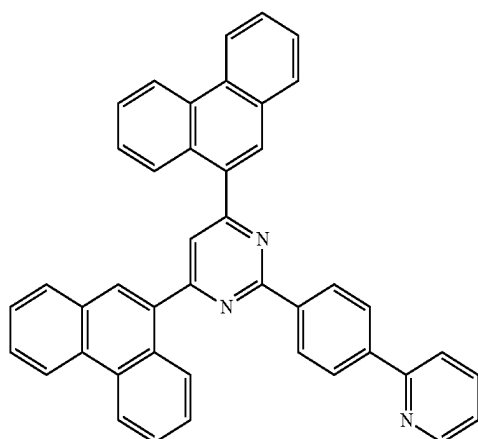
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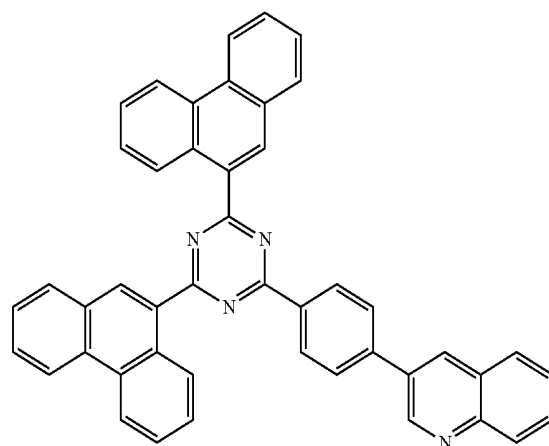


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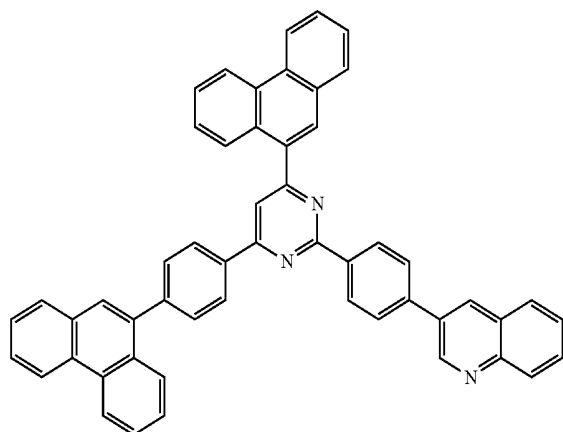
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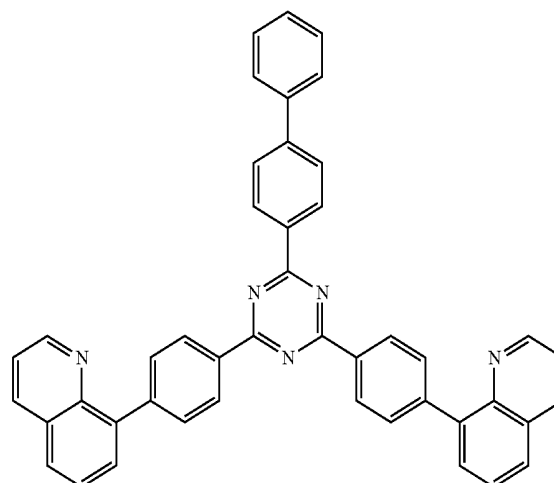
ET25



ET23

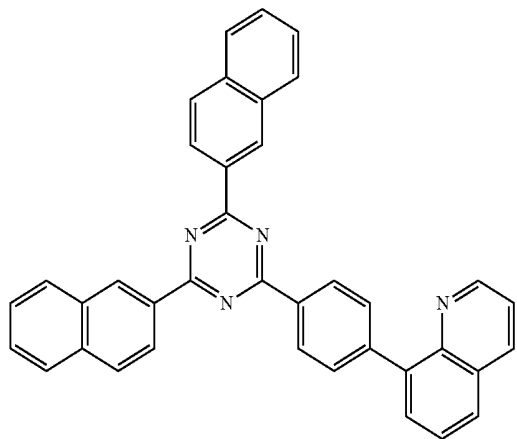


ET26



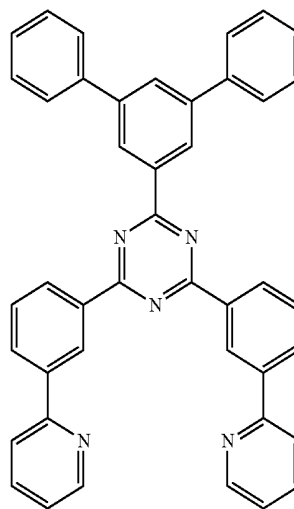
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ET27

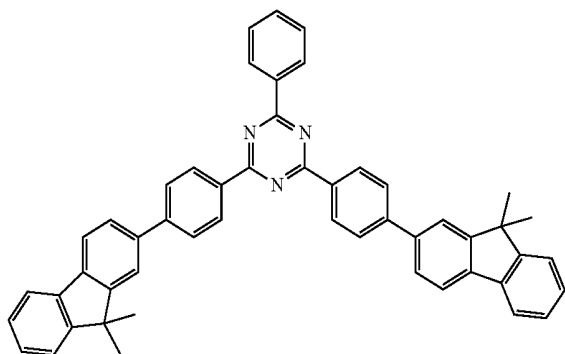


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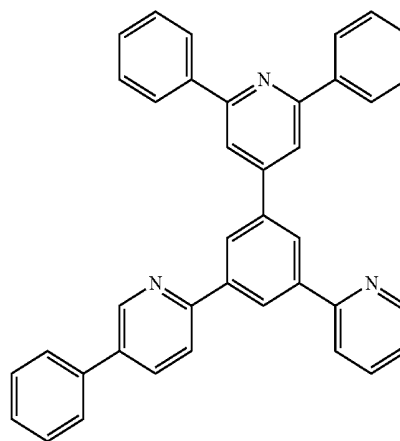
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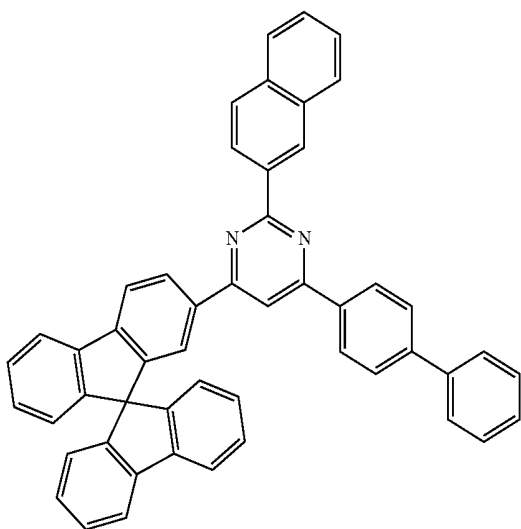
ET28



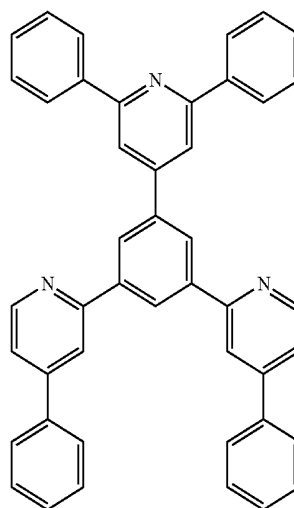
ET31



ET29

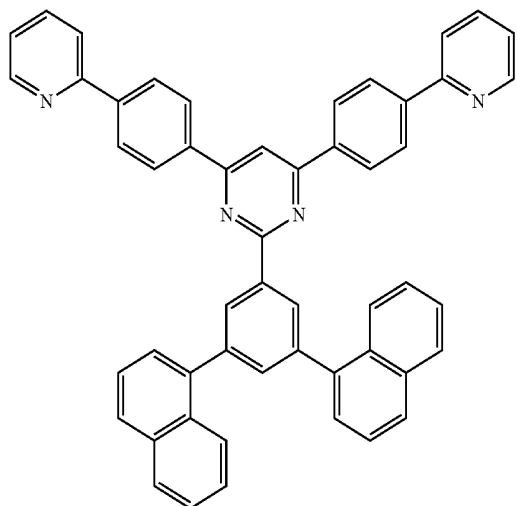


ET32



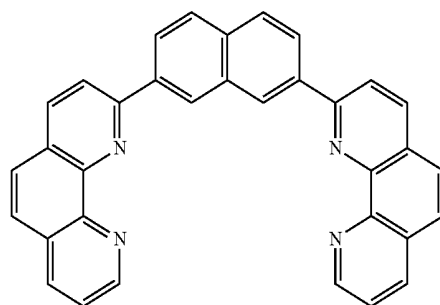
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ET33



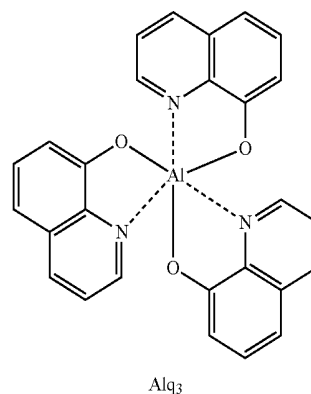
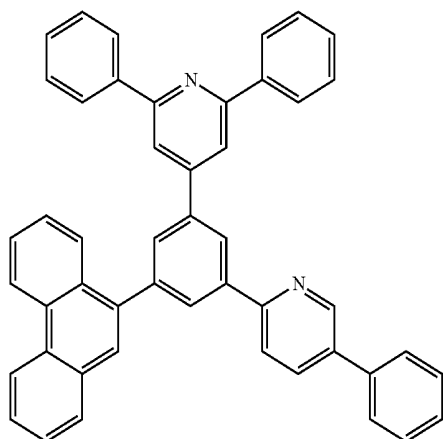
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ET36

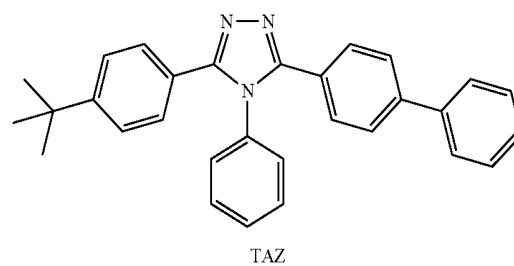
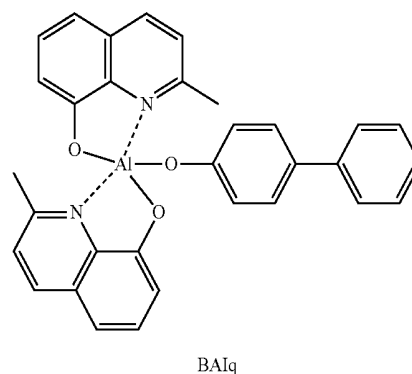
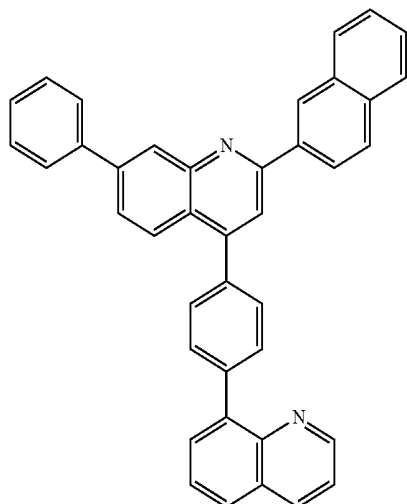


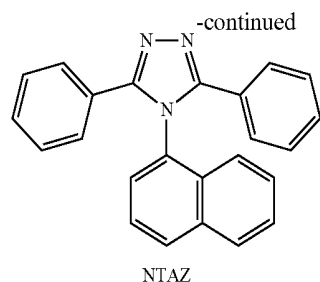
[0327] In an exemplary embodiment, the electron transport region may include at least one compound selected from 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP), 4,7-diphenyl-1,10-phenanthroline (Bphen), Alq₃, BAlq, 3-(biphenyl-4-yl)-5-(4-tert-butylphenyl)-4-phenyl-4H-1,2,4-triazole (TAZ), and NTAZ:

ET34



ET35





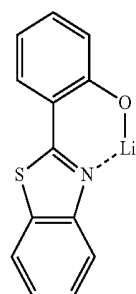
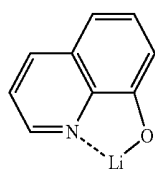
[0328] A thickness of the buffer layer, the hole blocking layer, or the electron control layer may each independently be in a range of from about 20 Å to about 1,000 Å, for example, from about 30 Å to about 300 Å. When the thicknesses of the buffer layer, the hole blocking layer, and the electron control layer are within any of these ranges, the electron blocking layer may have relatively high electron blocking characteristics and/or electron control characteristics, without a substantial increase in driving voltage.

[0329] A thickness of the electron transport layer may be in a range of from about 100 Å to about 1,000 Å, for example, from about 150 Å to about 500 Å. When the thickness of the electron transport layer is within any of these ranges, satisfactory electron transport characteristics may be obtained without a substantial increase in driving voltage.

[0330] The electron transport region (for example, an electron transport layer in the electron transport region) may include a material including metal.

[0331] The material including metal may include at least one selected from an alkali metal complex or an alkaline earth-metal complex. The alkali metal complex may include a metal ion selected from a lithium (Li) ion, a sodium (Na) ion, a potassium (K) ion, a rubidium (Rb), and a cesium (Cs) ion. The alkaline earth-metal complex may include a metal ion selected from a beryllium (Be) ion, a magnesium (Mg) ion, a calcium (Ca) ion, a strontium (Sr) ion, or a barium (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 hydroxyquinoline, a hydroxyisoquinoline, a hydroxybenzoquinoline, a hydroxyacridine, a hydroxyphenanthridine, a hydroxyphenyl oxazole, a hydroxyphenyl thiazole, a hydroxydiphenyl oxadiazole, a hydroxydiphenylthiadiazole, a hydroxyphenyl pyridine, a hydroxyphenyl benzimidazole, a hydroxyphenyl benzothiazole, a bipyridine, a phenanthroline, and a cyclopentadiene, but the embodiments are not limited thereto.

[0332] For example, the material including metal may include a lithium (Li) complex. The Li complex may include, for example, Compounds ET-D1 (lithium quinolate, LiQ) or ET-D2:



[0333] The electron transport region may include an electron injection layer which may facilitate electron injection from the second electrode **190**. The electron injection layer may directly contact the second electrode **190**.

[0334] The electron injection layer may have i) a single-layered structure 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.

[0335] 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.

[0336] The alkali metal may be selected from Li, Na, K, Rb, and Cs. In an exemplary embodiment, the alkali metal may be Li, Na, or Cs. In an exemplary embodiment, the alkali metal may be Li or Cs, but the embodiments are not limited thereto.

[0337] The alkaline earth-metal may be selected from Mg, Ca, Sr, and Ba.

[0338] The rare-earth metal may be selected from scandium (Sc), yttrium (Y), cerium (Ce), terbium (Tb), ytterbium (Yb), and gadolinium (Gd).

[0339] The alkali metal compound, the alkaline earth-metal compound, and the rare-earth metal compound may each 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.

[0340] The alkali metal compound may be selected from alkali metal oxides, such as Li_2O , Cs_2O , and K_2O , and alkali metal halides, such as LiF, NaF, CsF, KF, LiI, NaI, CsI, and KI. In an exemplary embodiment, the alkali metal compound may be selected from LiF, Li_2O , NaF, LiI, NaI, CsI, and KI, but the embodiments are not limited thereto.

[0341] The alkaline earth-metal compound may be selected from alkaline earth-metal compounds, such as BaO, SrO, CaO, $\text{Ba}_x\text{Sr}_{1-x}\text{O}$ ($0 < x < 1$), and $\text{Ba}_x\text{Ca}_{1-x}\text{O}$ ($0 < x < 1$). In an exemplary embodiment, the alkaline earth-metal compound may be selected from BaO, SrO, and CaO, but the embodiments are not limited thereto.

[0342] The rare-earth metal compound may be selected from YbF_3 , ScF_3 , ScQ_3 , Y_2O_3 , Ce_2O_3 , GdF_3 , and TbF_3 . In an exemplary embodiment, the rare-earth metal compound may be selected from YbF_3 , ScF_3 , TbF_3 , YbI_3 , ScI_3 , and TbI_3 , but the embodiments are not limited thereto.

[0343] The alkali metal complex, the alkaline earth-metal complex, and the rare-earth metal complex may each include

an alkali metal ion, an alkaline earth-metal ion, and a rare-earth metal ion as described above. 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 a hydroxyquinoline, a hydroxyisoquinoline, a hydroxybenzoquinoline, a hydroxyacridine, a hydroxyphenanthridine, a hydroxyphenyloxazole, a hydroxyphenylthiazole, a hydroxydiphenyloxadiazole, a hydroxydiphenylthiadiazol, a hydroxyphenylpyridine, a hydroxyphenylbenzimidazole, a hydroxyphenylbenzothiazole, a bipyridine, a phenanthroline, and a cyclopentadiene, but the embodiments are not limited thereto.

[0344] The electron injection layer may consist of an alkali metal, an alkaline earth-metal, a rare-earth-metal, an alkali metal compound, an alkaline earth-metal compound, a rare-earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare-earth metal complex, or any combination thereof, as described above. In an exemplary embodiment, 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.

[0345] A thickness of the electron injection layer may be in a range of from about 1 Å to about 100 Å, for example, from about 3 Å to about 90 Å. When the thickness of the electron injection layer is any of these ranges, satisfactory electron injection characteristics may be obtained without a substantial increase in driving voltage.

[Second Electrode 190]

[0346] The second electrode 190 may be dispersed on the organic layer 150. The second electrode 190 may be a cathode which is an electron injection electrode, and in this regard, the second electrode 190 may include a metal, an alloy, an electrically conductive compound, or any combination thereof, which may have a relatively low work function.

[0347] The second electrode 190 may include at least one selected from Li, Ag, Mg, Al, Al—Li, Ca, Mg—In, Mg—Ag, ITO, and IZO, but the embodiments are not limited thereto. The second electrode 190 may be a transmissive electrode, a semi-transmissive electrode, or a reflective electrode.

[0348] The second electrode 190 may have a single-layered structure. Alternatively, the second electrode 190 may have a multi-layered structure including two or more layers.

[Descriptions of FIGS. 2 to 4]

[0349] FIG. 2 is a schematic cross-sectional diagram illustrating an organic light-emitting device 20 according to an exemplary embodiment. Referring to FIG. 2, the organic light-emitting device 20 includes a first capping layer 210, the first electrode 110, the organic layer 150, and the second electrode 190. The first capping layer 210, the first electrode 110, the organic layer 150, and the second electrode 190 may

be sequentially stacked. FIG. 3 is a schematic cross-sectional diagram illustrating an organic light-emitting device 30 according to an exemplary embodiment. Referring to FIG. 3, the light-emitting device 30 includes the first electrode 110, the organic layer 150, the second electrode 190, and a second capping layer 220. The first electrode 110, the organic layer 150, the second electrode 190, and the second capping layer 220 may be sequentially stacked. FIG. 4 is a schematic cross-sectional diagram illustrating an organic light-emitting device 40 according to an exemplary embodiment. Referring to FIG. 4, the organic light-emitting device 40 includes the first capping layer 210, the first electrode 110, the organic layer 150, the second electrode 190, and the second capping layer 220. The first capping layer 210, the first electrode 110, the organic layer 150, the second electrode 190, and the second capping layer 220 may be sequentially stacked.

[0350] The first electrode 110, the organic layer 150, and the second electrode 190 of each of the organic light-emitting devices 20 to 40 of FIGS. 2 to 4 may be the same as defined those of FIG. 1.

[0351] In the organic layer 150 of each of the organic light-emitting devices 20 and 40, light generated in the emission layer may pass through the first electrode 110 and the first capping layer 210 toward the outside. The first electrode 110 may be a semi-transmissive electrode or a transmissive electrode. In the organic layer 150 of each of the organic light-emitting devices 30 and 40, light generated in the emission layer may pass through the second electrode 190 and the second capping layer 220 toward the outside. The second electrode 190 may be a semi-transmissive electrode or a transmissive electrode.

[0352] The first capping layer 210 and the second capping layer 220 may increase external luminescent efficiency according to the principle of constructive interference.

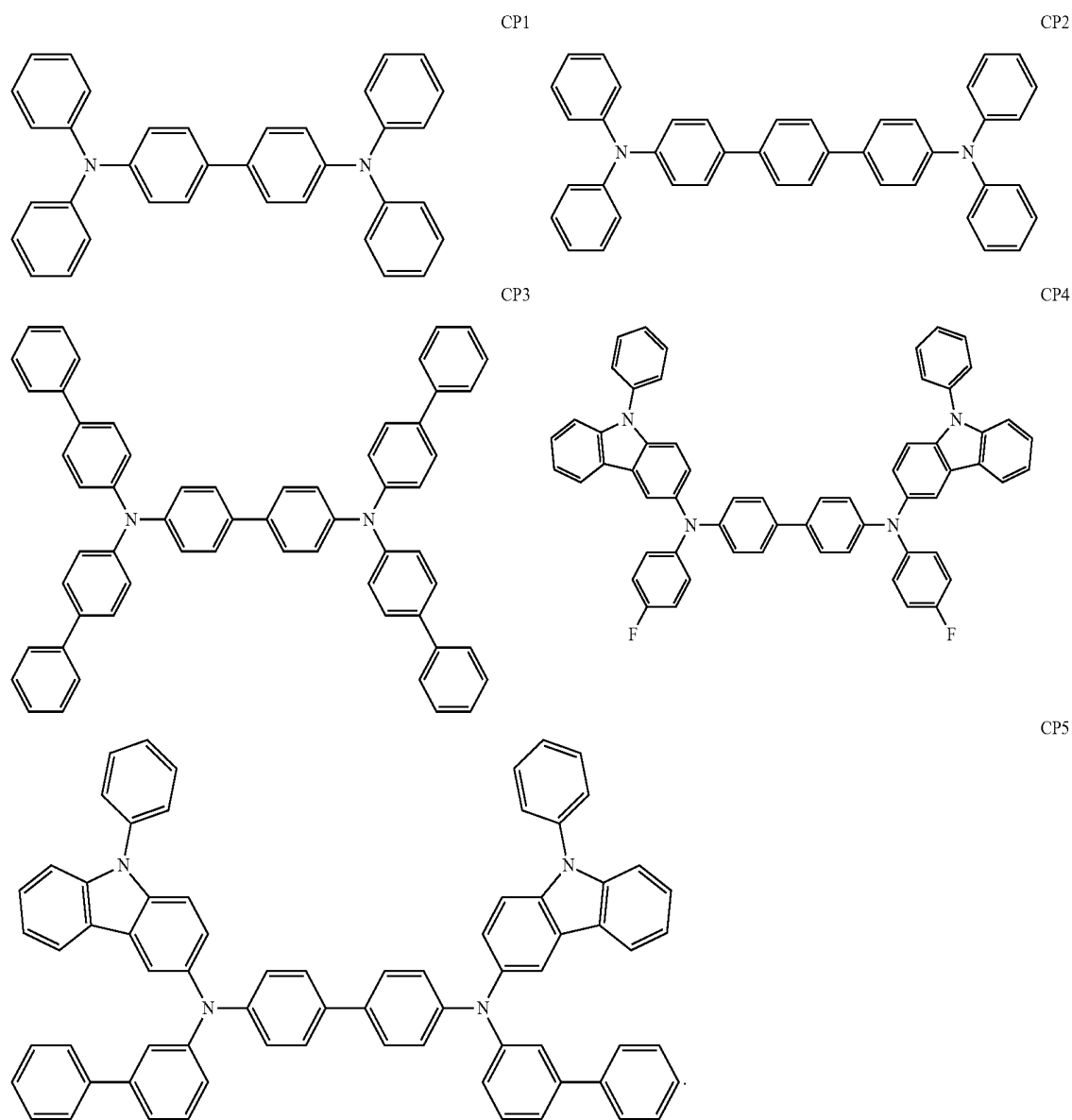
[0353] The first capping layer 210 and the second capping layer 220 may each independently be an organic capping layer including an organic material, an inorganic capping layer including an inorganic material, or a composite capping layer including an organic material and an inorganic material.

[0354] At least one of the first capping layer 210 and the second capping layer 220 may include at least one material selected from a carbocyclic compound, a heterocyclic compound, an amine-based compound, a porphine derivative, a phthalocyanine derivative, a naphthalocyanine derivative, an alkali metal complex, and an alkaline earth-metal complex. The carbocyclic compound, the heterocyclic compound, and the amine-based compound may be optionally substituted with a substituent including at least one element selected from O, N, S, Se, Si, F, Cl, Br, and I.

[0355] In an exemplary embodiment, at least one of the first capping layer 210 and the second capping layer 220 may include an amine-based compound.

[0356] In an exemplary embodiment, at least one of the first capping layer 210 and the second capping layer 220 may include a compound represented by Formula 201 or a compound represented by Formula 202.

[0357] In an exemplary embodiment, at least one of the first capping layer 210 and the second capping layer 220 may include a compound selected from Compounds HT28 to HT33 and Compounds CP1 to CP5, but the embodiments are not limited thereto:



[0358] Hereinabove, the organic light-emitting device according to an exemplary embodiment has been described with reference to FIGS. 1 to 4, but the embodiments are not limited thereto.

[0359] Layers constituting the hole transport region, an emission layer, and layers constituting the electron transport region may be formed in a certain region by using one or more suitable methods selected from vacuum deposition, spin coating, casting, Langmuir-Blodgett (LB) deposition, ink-jet printing, layer-printing, and laser-induced thermal imaging (LITI).

[0360] When the respective layers of the hole transport region, the emission layer, and the electron transport region are formed by vacuum deposition, for example, the vacuum deposition may be performed at a deposition temperature of from about 100° C. to about 500° C., at a vacuum degree of from about 10⁻⁸ torr to about 10⁻³ torr, and at a deposition rate of from about 0.01 Å/sec to about 100 Å/sec, depending

on the compound to be included in each layer, and the intended structure of each layer.

[0361] When the layers included in the hole transport region, the emission layer, and the layers included in electron transport region are formed by spin coating, for example, the spin coating may be performed at a coating speed of from about 2,000 rpm to about 5,000 rpm, and at a temperature of from about 80° C. to 200° C., depending on the compound to be included in each layer, and the structure of the layer to be formed.

[General Definition of Substituents]

[0362] The term “C₁-C₆₀ alkyl group” as used herein refers to a linear or branched saturated aliphatic hydrocarbon monovalent group having 1 to 60 carbon atoms, and non-limiting examples thereof include a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, a pentyl group, an iso-amyl group, and a

hexyl group. The term “C₁-C₆₀ alkylene group” as used herein refers to a divalent group having the same structure as the C₁-C₆₀ alkyl group.

[0363] The term “C₂-C₆₀ alkenyl group” as used herein refers to a hydrocarbon group formed by substituting at least one carbon-carbon double bond in the middle or at the terminus of the C₂-C₆₀ alkyl group, and non-limiting examples thereof include an ethenyl group, a propenyl group, and a butenyl group. The term “C₂-C₆₀ alkenylene group” as used herein refers to a divalent group having the same structure as the C₂-C₆₀ alkenyl group.

[0364] The term “C₂-C₆₀ alkynyl group” as used herein refers to a hydrocarbon group formed by substituting at least one carbon-carbon triple bond in the middle or at the terminus of the C₂-C₆₀ alkyl group, and non-limiting examples thereof include an ethynyl group, and a propynyl group. The term “C₂-C₆₀ alkynylene group” as used herein refers to a divalent group having the same structure as the C₂-C₆₀ alkynyl group.

[0365] 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 non-limiting examples thereof include a methoxy group, an ethoxy group, and an isopropoxy group.

[0366] The term “C₃-C₁₀ cycloalkyl group” as used herein refers to a monovalent saturated hydrocarbon monocyclic group having 3 to 10 carbon atoms, and non-limiting examples thereof include a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. The term “C₃-C₁₀ cycloalkylene group” as used herein refers to a divalent group having the same structure as the C₃-C₁₀ cycloalkyl group.

[0367] The term “C₁-C₁₀ heterocycloalkyl group” as used herein refers to a monovalent saturated monocyclic group having at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom and 1 to 10 carbon atoms, and non-limiting examples thereof include a 1,2,3,4-oxatriazolidiny group, a tetrahydrofuran group, and a tetrahydrothiophenyl group. The term “C₁-C₁₀ heterocycloalkylene group” as used herein refers to a divalent group having the same structure as the C₁-C₁₀ heterocycloalkyl group.

[0368] 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, and non-limiting examples thereof include a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. The term “C₃-C₁₀ cycloalkenylene group” as used herein refers to a divalent group having the same structure as the C₃-C₁₀ cycloalkenyl group.

[0369] 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. Non-limiting examples of the C₁-C₁₀ heterocycloalkenyl group include a 4,5-dihydro-1,2,3,4-oxatriazolyl group, a 2,3-dihydrofuran group and a 2,3-dihydrothiophenyl group. The term “C₁-C₁₀ heterocycloalkenylene group” as used herein refers to a divalent group having the same structure as the C₁-C₁₀ heterocycloalkenyl group.

[0370] The term “C₆-C₆₀ aryl group” as used herein refers to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms, and the term “C₆-C₆₀ arylene

group” as used herein refers to a divalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms. Non-limiting examples of the C₆-C₆₀ aryl group include a phenyl group, a naphthyl group, an anthracenyl group, a phenanthrenyl group, a pyrenyl group, and a chrysenyl group. When the C₆-C₆₀ aryl group and the C₆-C₆₀ arylene group each include two or more rings, the rings may be fused to each other.

[0371] The term “C₁-C₆₀ heteroaryl group” as used herein refers to a monovalent group having a heterocyclic aromatic system that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, in addition to 1 to 60 carbon atoms. The term “C₁-C₆₀ heteroarylene group” as used herein refers to a divalent group having a heterocyclic aromatic system that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, in addition to 1 to 60 carbon atoms. Non-limiting examples of the C₁-C₆₀ heteroaryl group include a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, and an isoquinolinyl group. When the C₁-C₆₀ heteroaryl group and the C₁-C₆₀ heteroarylene group each include two or more rings, the rings may be fused to each other.

[0372] 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).

[0373] The term “monovalent non-aromatic condensed polycyclic group” as used herein refers to a monovalent group (for example, having 8 to 60 carbon atoms) having two or more rings condensed with each other, only carbon atoms as ring-forming atoms, and no aromaticity in the entire molecular structure. A detailed example of the monovalent non-aromatic condensed polycyclic group is a fluorenyl group. The term “divalent non-aromatic condensed polycyclic group” as used herein refers to a divalent group having the same structure as the monovalent non-aromatic condensed polycyclic group.

[0374] The term “monovalent non-aromatic condensed heteropolycyclic group” as used herein refers to a monovalent group (for example, having 1 to 60 carbon atoms) having two or more rings condensed to each other, at least one heteroatom selected from N, O, Si, P, and S, other than carbon atoms, as a ring-forming atom, and no aromaticity in the entire molecular structure. An example of the monovalent non-aromatic condensed heteropolycyclic group is a carbazolyl group.

[0375] The term “C₅-C₆₀ carbocyclic group” as used herein refers to a monocyclic or polycyclic group having 5 to 60 carbon atoms in which a ring-forming atom is a carbon atom only. The C₅-C₆₀ carbocyclic group may be an aromatic carbocyclic group or a non-aromatic carbocyclic group. The C₅-C₆₀ carbocyclic group may be a ring same as a benzene, a monovalent group such as a phenyl group, or a divalent group such as a phenylene group. In an exemplary embodiment, depending on the number of substituents connected to the C₅-C₆₀ carbocyclic group, the C₅-C₆₀ carbocyclic group may be a trivalent group or a quadrivalent group.

[0376] The term “C₁-C₆₀ heterocyclic group” as used herein refers to a group having the same structure as the C₅-C₆₀ carbocyclic group, except that as a ring-forming atom, at least one heteroatom selected from N, O, Si, P, and

S is used in addition to carbon (the number of carbon atoms may be in a range of 1 to 60).

[0377] At least one substituent of the substituted C₅-C₆₀ carbocyclic group, the substituted C₁-C₆₀ heterocyclic group, the substituted C₃-C₁₀ cycloalkylene group, the substituted C₁-C₁₀ heterocycloalkylene group, the substituted C₃-C₁₀ cycloalkenylene group, the substituted C₁-C₁₀ heterocycloalkenylene group, the substituted C₆-C₆₀ arylene group, the substituted C₁-C₆₀ heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, the substituted divalent non-aromatic condensed heteropolycyclic group, the substituted C₁-C₆₀ alkyl group, the substituted C₂-C₆₀ alkenyl group, the substituted C₂-C₆₀ alkynyl group, the substituted C₁-C₆₀ alkoxy group, the substituted C₃-C₁₀ cycloalkyl group, the substituted C₁-C₁₀ heterocycloalkyl group, the substituted C₃-C₁₀ cycloalkenyl group, the substituted C₁-C₁₀ heterocycloalkenyl group, the substituted C₆-C₆₀ aryl group, the substituted C₆-C₆₀ aryloxy group, the substituted C₆-C₆₀ arylthio group, the substituted C₁-C₆₀ heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from:

[0378] 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;

[0379] a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —Si(Q₁₁)(Q₁₂)(Q₁₃), —N(Q₁₁)(Q₁₂), —B(Q₁₁)(Q₁₂), —C(=O)(Q₁₁), —S(=O)₂(Q₁₁), and —P(=O)(Q₁₁)(Q₁₂);

[0380] a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

[0381] a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

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

[0382] —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and

[0383] Q₁₁ to Q₁₃, Q₂₁ to Q₂₃, and Q₃₁ to Q₃₃ may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

[0384] 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 “ter-Bu” or “But” as used herein refers to a tert-butyl group, and the term “OMe” as used herein refers to a methoxy group.

[0385] The term “biphenyl group” as used herein refers to “a phenyl group substituted with a phenyl group.” As an example, “a biphenyl group” is a substituted phenyl group having a “C₆-C₆₀ aryl group” as a substituent.

[0386] The term “terphenyl group” as used herein refers to “a phenyl group substituted with a biphenyl group.” As an example, a terphenyl group is a substituted phenyl group having a “C₆-C₆₀ aryl group.”

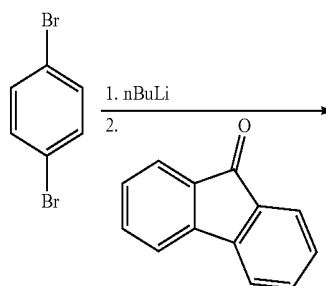
[0387] The symbols * and *¹ as used herein, unless defined otherwise, refer to a binding site to a neighboring atom in a corresponding formula.

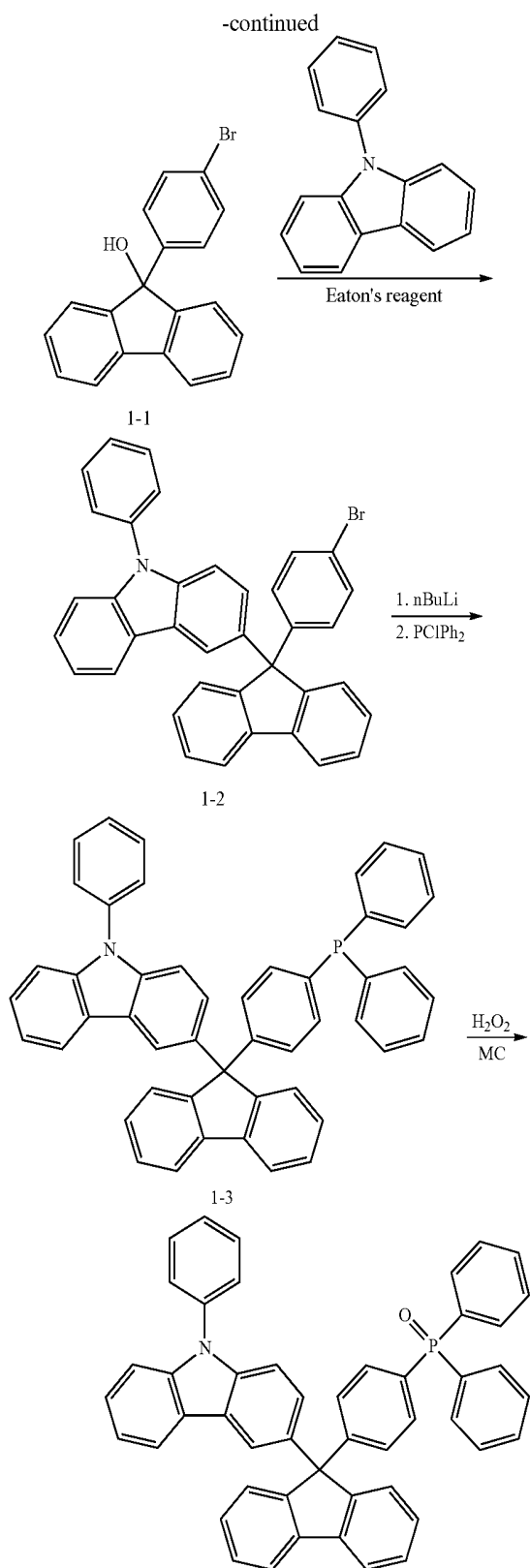
[0388] A condensed cyclic compound according to one or more exemplary embodiments of the present invention and an organic light-emitting device according one or more exemplary embodiments of the present invention will be described in more detail below with reference to Synthesis Examples and Examples. The wording “B was used instead of A” as used in describing Synthesis Examples refers to an example in which a molar equivalent of B was used in place of A.

EXAMPLES

Synthesis Example 1: Synthesis of Compound 1

[0389]





Synthesis of Intermediate 1-1

[0390] 1,4-dibromobenzene was allowed to react with n-butyllithium, and then, 9-fluorenone was added thereto

drop by drop, thereby obtaining Intermediate 1-1. The obtained compound was identified using LC/MS.

[0391] 1-1 $C_{19}H_{13}BrO$ M+1: 337.1

Synthesis of Intermediate 1-2

[0392] Intermediate 1-1 was allowed to react with N-phenylcarbazole and Eaton's reagent (CAS No.: 3934-84-8), thereby obtaining Intermediate 1-2. The obtained compound was identified using LC/MS.

[0393] 1-2 $C_{37}H_{24}BrN$ M+1: 561.21

Synthesis of Intermediate 1-3

[0394] Intermediate 1-2 was allowed to react with n-butyllithium, and then, chlorodiphenyl phosphine was added thereto drop by drop, thereby obtaining Intermediate 1-3. The obtained compound was identified using LC/MS.

[0395] 1-3 $C_{49}H_{34}NP$ M+1: 668.33

Synthesis of Compound 1

[0396] 5 g of Intermediate 1-3 was dissolved in 50 mL of methylene chloride (MC), and then, 10 mL of 30% hydrogen peroxide aqueous solution was slowly added thereto drop by drop. About 3 hours later, an extraction process using MC was performed thereon, and an organic layer collected therefrom was then washed using water. The organic layer was dried using magnesium sulfate ($MgSO_4$), and a solvent was evaporated therefrom. The resulting residue was purified by silica gel column chromatography, thereby obtaining 3.7 g (yield: 72%) of Compound 1. The obtained compound was identified using LC-MS and 1H -NMR.

Synthesis Example 2: Synthesis of Compound 5

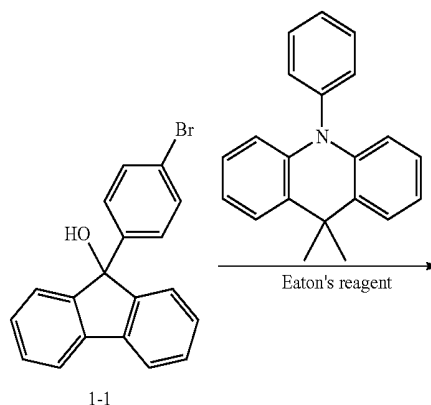
[0397] 2.5 g (yield: 52%) of Compound 5 was obtained in substantially the same manner as in synthesizing Compound 1 according to Synthesis Example 1, except that 5-phenyl-5H-pyrido[3,2-b]indole (CAS No.: 1541200-53-6) was used instead of N-phenylcarbazole. The obtained compound was identified using LC-MS and 1H -NMR.

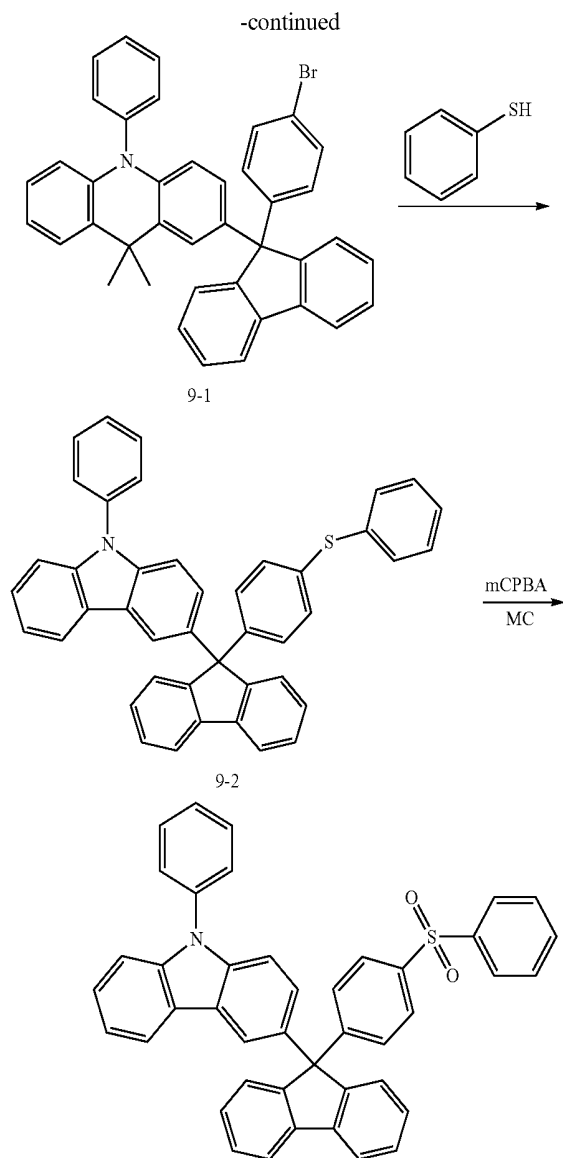
Synthesis Example 3: Synthesis of Compound 6

[0398] 3.8 g (yield: 66%) of Compound 6 was obtained in substantially the same manner as in synthesizing Compound 1 according to Synthesis Example 1, except 9,9-dimethyl-10-phenyl-9,10-dihydroacridine (CAS No.: 717880-39-2) was used instead of N-phenylcarbazole. The obtained compound was identified using LC-MS and 1H NMR.

Synthesis Example 4: Synthesis of Compound 9

[0399]





Synthesis of Intermediate 9-1

[0400] Intermediate 1-1 and 9,9-dimethyl-10-phenyl-9,10-dihydroacridine were dissolved in an MC, and then, the mixed solution was allowed to react with Eaton's reagent, thereby obtaining Intermediate 9-1.

[0401] 9-1 $C_{40}H_{30}BrN$ M+1: 604.33

Synthesis of Intermediate 9-2

[0402] Intermediate 9-1 was allowed to react with thiophenyl in the presence of a copper catalyst, thereby obtaining Intermediate 9-2.

[0403] 9-2 $C_{43}H_{29}NS$ M+1: 592.3

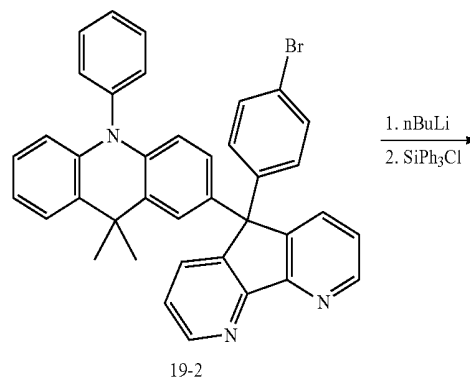
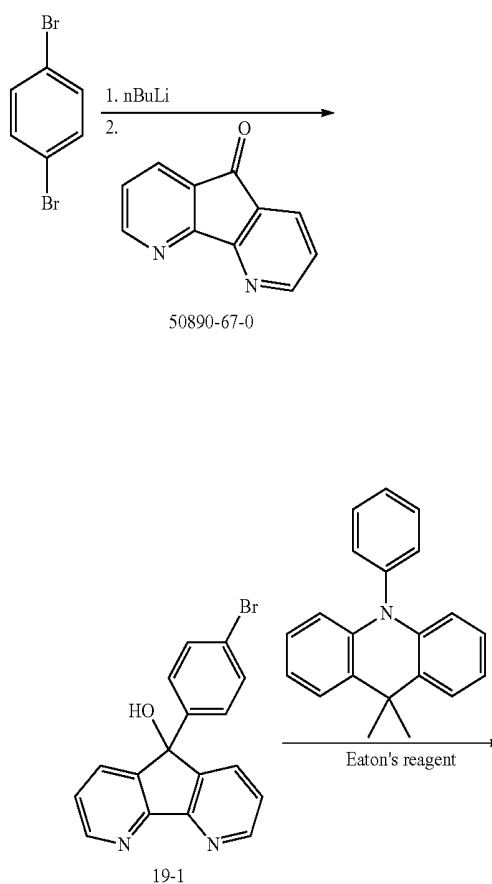
Synthesis of Compound 9

[0404] 4.5 g of Intermediate 9-2 was dissolved in 50 mL of an MC, and then, 2.9 g of mCPBA was slowly added thereby drop by drop. About 3 hours later, an extraction process using MC was performed thereon, and an organic layer collected therefrom was then washed using sodium

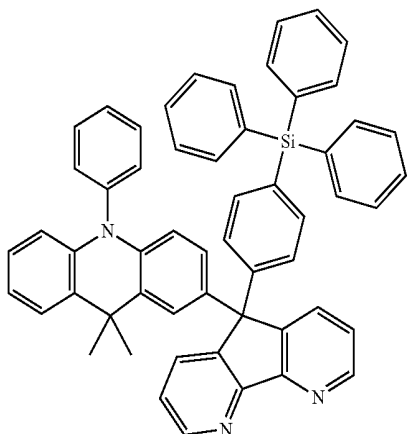
hydrogen carbonate. The organic layer was dried using $MgSO_4$, and a solvent was evaporated therefrom. The resulting residue was purified by silica gel column chromatography, thereby obtaining 2.4 g (yield: 57%) of Compound 9. The obtained compound was identified using LC-MS and 1H -NMR.

Synthesis Example 5: Synthesis of Compound 19

[0405]



-continued



Synthesis of Intermediate 19-1

[0406] 1,4-dibromobenzene was allowed to react with n-butyllithium and subsequently with 5H-cyclopenta[2,1-b:3,4-b']dipyridine-5-on (CAS No.: 50890-67-0), thereby obtaining Intermediate 19-1.

[0407] 19-1 $C_{17}H_{11}BrN_2O$ M+1: 339.14

Synthesis of Intermediate 19-2

[0408] Intermediate 19-1 was allowed to react with 9,9-dimethyl-10-phenyl-9,10-dihydroacridine in the presence of Eaton's reagent, thereby obtaining Intermediate 19-2.

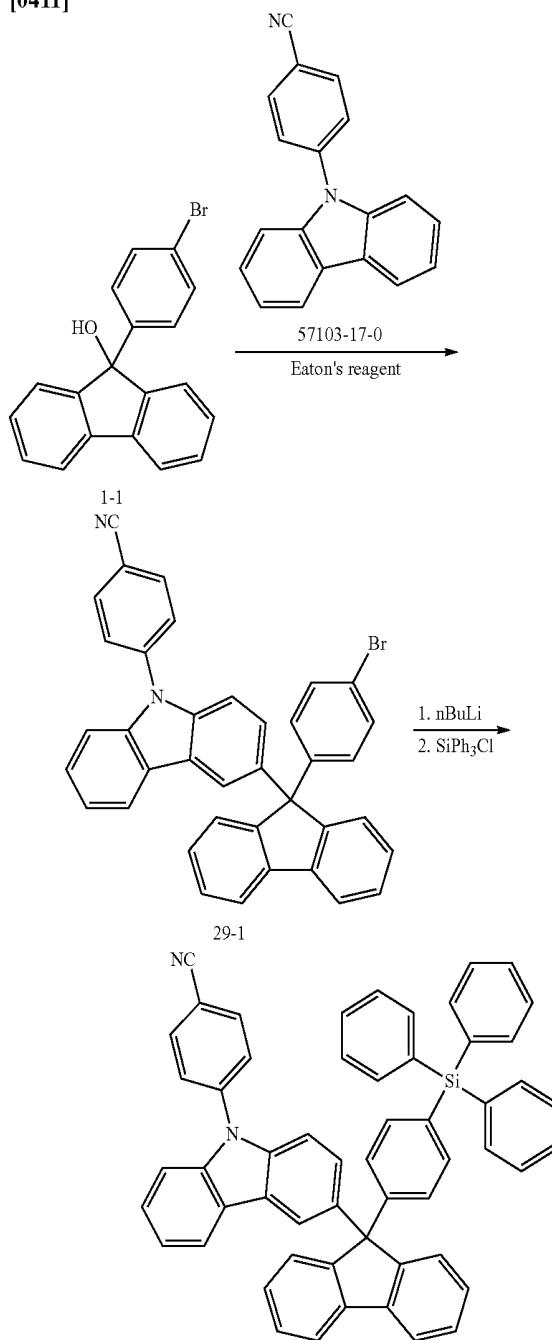
[0409] 19-2 $C_{38}H_{28}BrN_3$ M+1: 606.29

Synthesis of Compound 19

[0410] 3.3 g of Intermediate 19-2 was dissolved in 30 mL of tetrahydrofuran (THF), and at a temperature of about $-78^\circ C$., 2.2 mL of n-butyllithium (2 M solution in n-hexane) was slowly added thereto drop by drop. About 1.5 hours later, 1.6 g of triphenylchlorosilane was added to the mixed solution drop by drop. A temperature at which the reaction occurs in the mixed solution was raised up to room temperature, and then, stirring was performed thereon overnight. Distilled water was added thereto drop by drop to complete the reaction, and an extraction process using ethylacetate was performed thereon. An organic layer collected therefrom was then dried using $MgSO_4$, and a solvent was evaporated therefrom. The resulting residue was purified by silica gel column chromatography, thereby obtaining 3.4 g (yield: 81%) of Compound 19. The obtained compound was identified using LC-MS and 1H -NMR.

Synthesis Example 6: Synthesis of Compound 29

[0411]



Synthesis of Intermediate 29-1

[0412] Compound 1-1 was allowed to react with 4-(9H-carbazole-9-yl)benzonitrile in the presence of Eaton's reagent, thereby obtaining Intermediate 29-1.

[0413] 29-1 $C_{38}H_{23}BrN_2$ M+1: 587.22

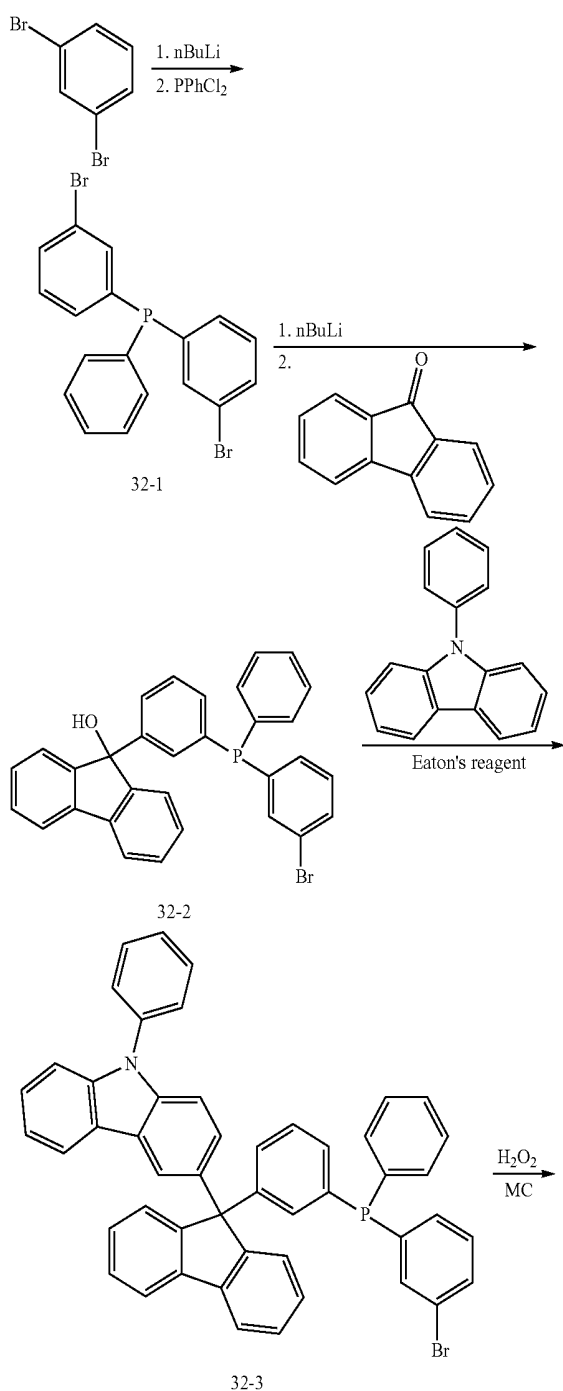
Synthesis of Compound 29

[0414] 2.9 g of Intermediate 29-1 was dissolved in 30 mL of THF, and at a temperature of about $-78^\circ C$., 2.5 mL of n-butyllithium (2 M solution in n-hexane) was slowly added thereto drop by drop. About 1.5 hours later, a THF solution in which triphenylchlorosilane was dissolved was added thereto drop by drop. A temperature at which the reaction

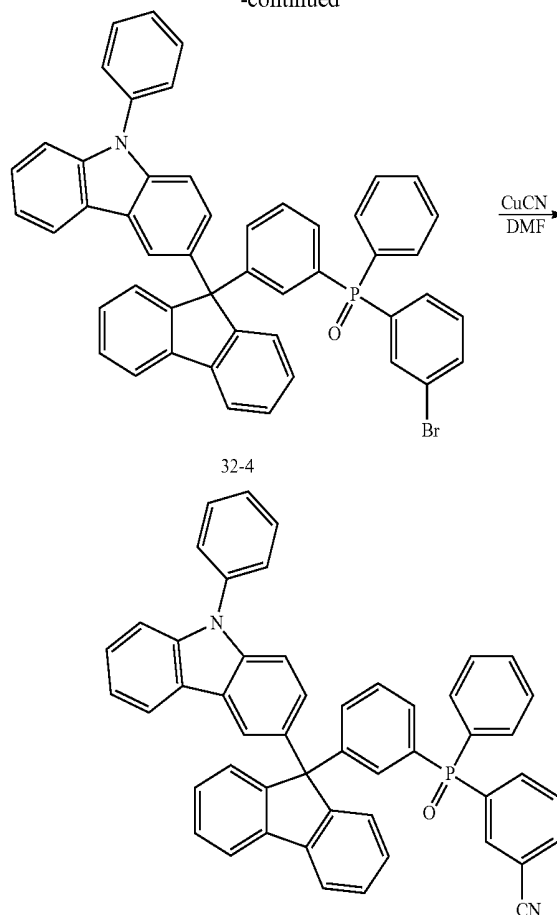
occurs in the mixed solution was raised up to room temperature, and then, stirring was performed thereon overnight. Distilled water was added thereto drop by drop to complete the reaction, and an extraction process using ethylacetate was performed thereon. An organic layer collected therefrom was then dried using MgSO_4 , and a solvent was evaporated therefrom. The resulting residue was purified by silica gel column chromatography, thereby obtaining 2.6 g (yield: 69%) of Compound 29. The obtained compound was identified using LC-MS and $^1\text{H-NMR}$.

Synthesis Example 7: Synthesis of Compound 32

[0415]



-continued



Synthesis of Intermediate 32-1

[0416] 1,3-dibromobenzene was allowed to react with n -butyllithium and subsequently with dichlorophenylphosphine, thereby obtaining Intermediate 32-1.

[0417] 32-1 $\text{C}_{18}\text{H}_{13}\text{Br}_2\text{P}$ M+1: 418.99

Synthesis of Intermediate 32-2

[0418] Intermediate 32-1 was allowed to react with n -butyllithium subsequently with 9-fluorenone, thereby obtaining Intermediate 32-2.

[0419] 32-2 $\text{C}_{31}\text{H}_{22}\text{BrOP}$ M+1: 521.11

Synthesis of Intermediate 32-3

[0420] Intermediate 32-2 was allowed to react with N -phenylcarbazole in the presence of Eaton's reagent, thereby obtaining Intermediate 32-3.

[0421] 32-3 $\text{C}_{49}\text{H}_{33}\text{BrNP}$ M+1: 746.25

Synthesis of Intermediate 32-4

[0422] Intermediate 32-3 was subjected to oxidation using hydrogen peroxide, thereby obtaining Intermediate 32-4.

[0423] 32-4 $\text{C}_{49}\text{H}_{33}\text{BrNOP}$ M+1: 761.34

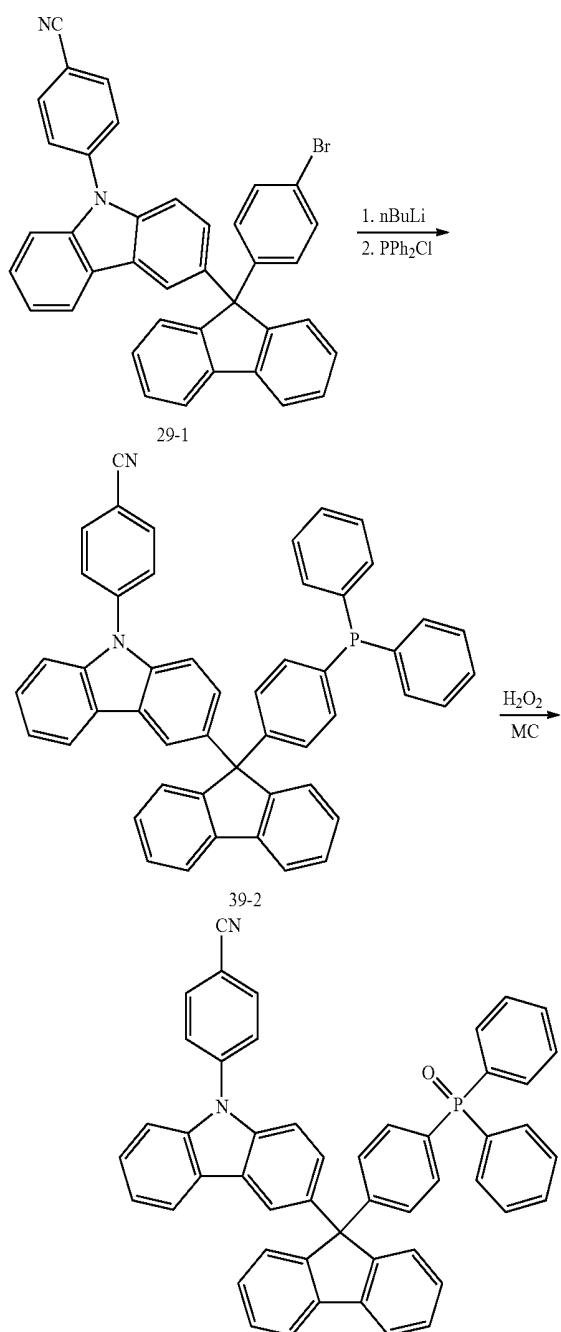
Synthesis of Compound 32

[0424] 5.7 g of Intermediate 32-4 was dissolved in dimethylformamide (DMF), and 1 g of CuCN was added thereto

while stirring was performed overnight. Distilled water was added to the mixed solution drop by drop to complete the reaction, and an extraction process using ethylacetate was performed thereon. An organic layer collected therefrom was then dried using MgSO_4 , and a solvent was evaporated therefrom. The resulting residue was purified by silica gel column chromatography, thereby obtaining 3 g (yield: 56%) of Compound 32. The obtained compound was identified using LC-MS and $^1\text{H-NMR}$.

Synthesis Example 8: Synthesis of Compound 39

[0425]



Synthesis of Intermediate 39-2

[0426] Intermediate 29-1 was allowed to react with n -butyllithium and subsequently with chlorodiphenyl phosphine, thereby obtaining Intermediate 39-2.

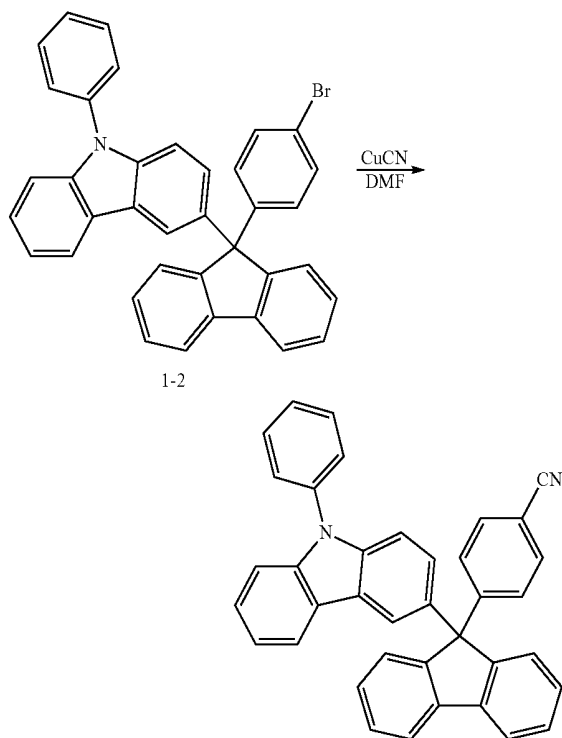
[0427] 39-2 $\text{C}_{50}\text{H}_{33}\text{N}_2\text{P}$ $M+1$: 693.37

Synthesis of Compound 39

[0428] 6.2 g of Intermediate 39-2 was dissolved in MC , and then, 10 mL of 30% hydrogen peroxide aqueous solution was slowly added thereto drop by drop. About 3 hours later, an extraction process using MC was performed thereon, and an organic layer collected therefrom was then washed using water. The organic layer was dried using MgSO_4 , and a solvent was evaporated therefrom. The resulting residue was purified by silica gel column chromatography, thereby obtaining 5.5 g (yield: 87%) of Compound 39. The obtained compound was identified using LC-MS and $^1\text{H-NMR}$.

Synthesis Example 9: Synthesis of Compound 42

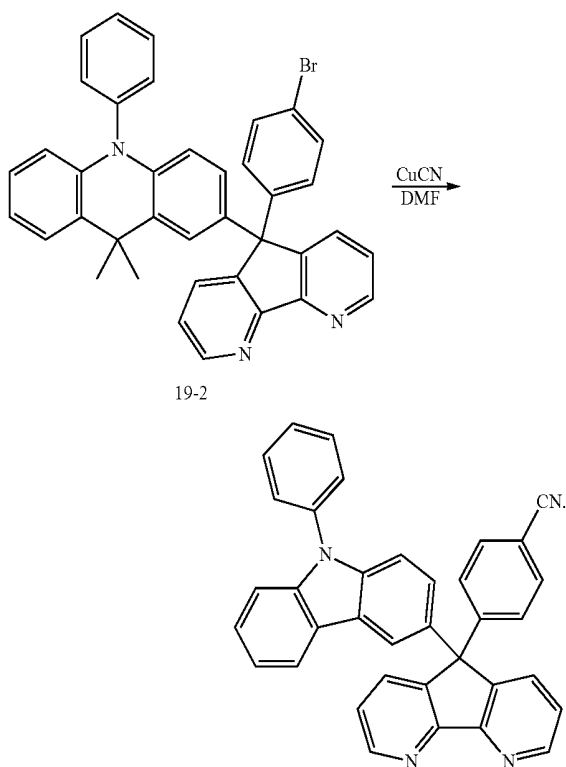
[0429]



[0430] 4.1 g of Intermediate 1-2 was dissolved in 15 mL of DMF , and then, 1 g of CuCN was added thereto while stirring was performed overnight. Distilled water was added to the mixed solution drop by drop to complete the reaction, and an extraction process using ethylacetate was performed thereon. An organic layer collected therefrom was then dried using MgSO_4 , and a solvent was evaporated therefrom. The resulting residue was purified by silica gel column chromatography, thereby obtaining 2.6 g (yield: 71%) of Compound 42. The obtained compound was identified using LC-MS and $^1\text{H-NMR}$.

Synthesis Example 10: Synthesis of Compound 48

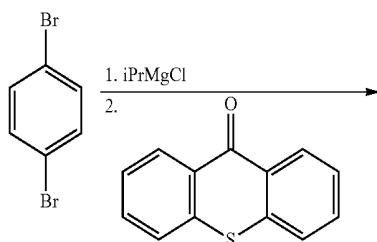
[0431]



[0432] 4.9 g of Intermediate 19-2 was dissolved in 50 mL of DMF, and then, 0.73 g of CuCN was added thereto while stirring was performed overnight. Distilled water was added to the mixed solution drop by drop to complete the reaction, and an extraction process using ethylacetate was performed thereon. An organic layer collected therefrom was then dried using MgSO_4 , and a solvent was evaporated therefrom. The resulting residue was purified by silica gel column chromatography, thereby obtaining 1.9 g (yield: 42%) of Compound 48. The obtained compound was identified using LC-MS and $^1\text{H-NMR}$.

Synthesis Example 11: Synthesis of Compound 51

[0433]



Synthesis of Intermediate 51-1

[0434] 1,4-dibromobenzene was allowed to react with iPrMgCl and subsequently with 9H-thioxanthen-9-one, thereby obtaining Intermediate 51-1.

[0435] 51-1 $\text{C}_{19}\text{H}_{13}\text{BrOS}$ M+1: 369.01

Synthesis of Intermediate 51-2

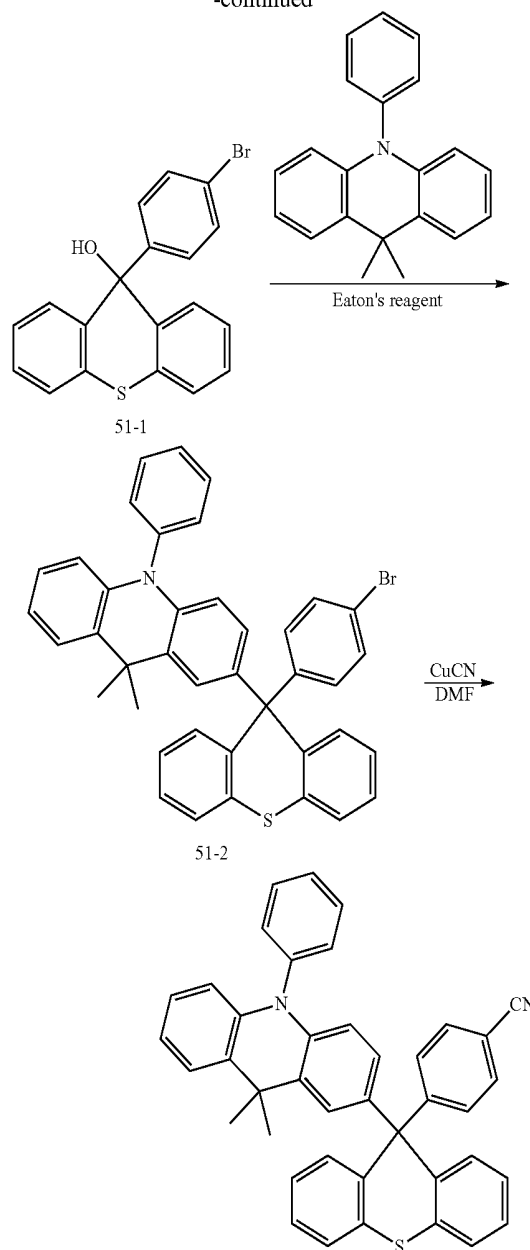
[0436] Intermediate 51-1 was allowed to react with 9,9-dimethyl-10-phenyl-9,10-dihydroacridine in the presence of Eaton's reagent, thereby obtaining Intermediate 51-2.

[0437] 51-2 $\text{C}_{40}\text{H}_{30}\text{BrNS}$ M+1: 636.26

Synthesis of Compound 51

[0438] 3.9 g of Intermediate 51-2 was dissolved in DMF, and then, 0.55 g of CuCN was added thereto while stirring

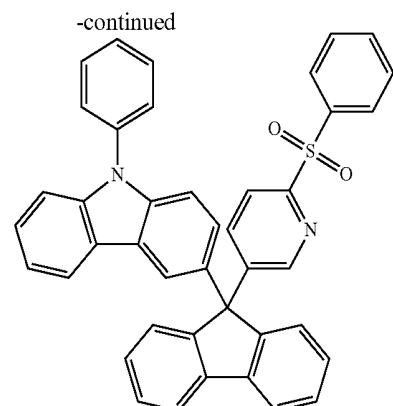
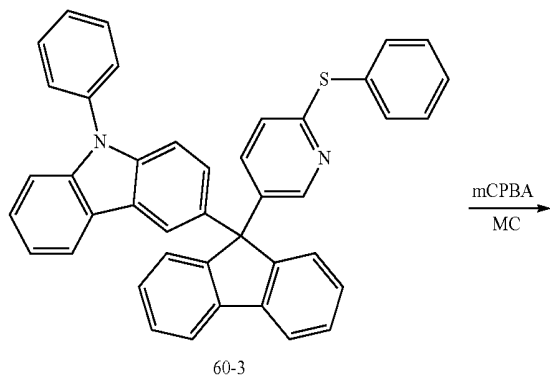
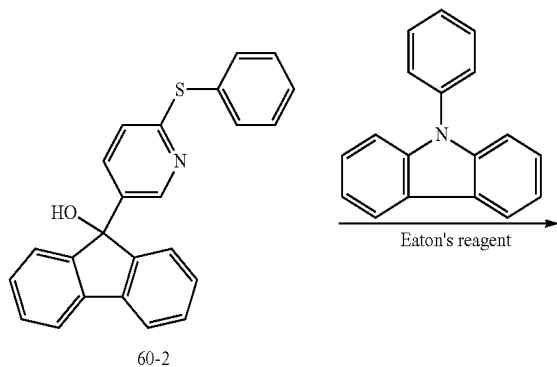
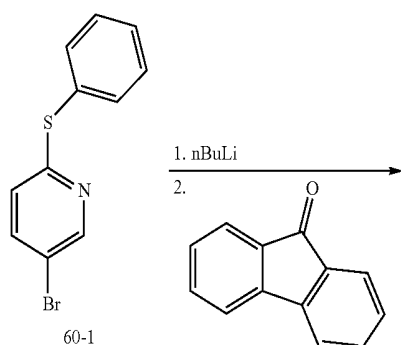
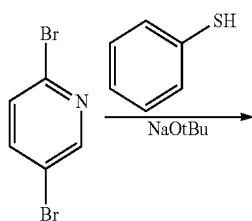
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was performed overnight. Distilled water was added to the mixed solution drop by drop to complete the reaction, and an extraction process using ethylacetate was performed thereon. An organic layer collected therefrom was then dried using $MgSO_4$, and a solvent was evaporated therefrom. The resulting residue was purified by silica gel column chromatography, thereby obtaining 1.7 g (yield: 49%) of Compound 51. The obtained compound was identified using LC-MS and 1H -NMR.

Synthesis Example 12: Synthesis of Compound 60

[0439]



Synthesis of Intermediate 60-1

[0440] 2,5-dibromopyridine was allowed to react with thiophenol under basic conditions, thereby obtaining Intermediate 60-1.

[0441] 60-1 $C_{11}H_8BrNS$ M+1: 265.88

Synthesis of Intermediate 60-2

[0442] Intermediate 60-1 was allowed to react with n-butyllithium, and then, 9-fluorenone was slowly added thereto drop by drop, thereby obtaining Intermediate 60-2.

[0443] 60-2 $C_{24}H_{17}NOS$ M+1: 368.12

Synthesis of Intermediate 60-3

[0444] Intermediate 51-1 was allowed to react with N-phenylcarbazole in the presence of Eaton's reagent, thereby obtaining Intermediate 60-3.

[0445] 60-3 $C_{42}H_{28}N_2S$ M+1: 593.32

Synthesis of Compound 60

[0446] 5 g of Intermediate 60-3 was dissolved in 50 mL of MC, and then, 3.6 g of mCPBA was slowly added thereto drop by drop. About 3 hours later, an extraction process using dichloromethane MC was performed thereon, and an organic layer collected therefrom was then washed using sodium hydrogen carbonate. The organic layer was dried using $MgSO_4$, and a solvent was evaporated therefrom. The resulting residue was purified by silica gel column chromatography, thereby obtaining 2.7 g (yield: 52%) of Compound 60. The obtained compound was identified using LC-MS and 1H -NMR.

Synthesis Example 13: Synthesis of Compound 71

[0447] 3.9 g (yield: 61%) of Compound 71 was obtained in substantially the same manner as in synthesizing Compound 1 according to Synthesis Example 1, except that 9,9,10-triphenyl-9,10-dihydroacridine was used instead of 9,9-dimethyl-10-phenyl-9,10-dihydroacridine.

[0448] The results of 1H NMR and MS/FAB regarding the compounds synthesized according to Synthesis Examples 1 to 13 are shown in Table 1.

[0449] Compounds other than the compounds listed in Table 1 may be synthesized in a substantially the same manner by one of ordinary skill in the art by referring to the above synthesis pathways and materials.

TABLE 1

Compound	¹ H NMR (CDCl ₃ , 400 MHz)	MS/FAB	
		Found [M + 1]	calc.
1	8.82 (s, 1H), 8.19 (d, 1H), 7.92-7.75 (m, 10H), 7.60-7.52 (m, 14H), 7.35-7.21 (m, 7H), 6.97 (d, 1H)	684.33	683.24
5	8.77 (s, 1H), 8.44 (d, 1H), 7.92-7.52 (m, 23H), 7.41-7.18 (m, 7H), 6.98 (d, 1H), 6.97 (d, 1H)	685.52	684.23
6	7.93 (d, 2H), 7.80-7.70 (m, 7H), 7.56-7.49 (m, 7H), 7.42-7.35 (m, 4H), 7.30-6.99 (m, 13H), 6.75 (d, 1H), 1.65 (s, 6H)	726.21	725.28
9	7.91 (d, 2H), 7.82-7.75 (m, 4H), 7.57-7.52 (m, 5H), 7.39-7.32 (m, 4H), 7.30-6.92 (m, 13H), 6.77 (d, 1H), 1.65 (s, 6H)	666.25	665.24
19	8.37 (d, 2H), 7.52-7.42 (m, 10H), 7.39 (m, 9), 7.29-6.92 (m, 13), 6.82 (t, 2H), 6.74 (d, 1H), 1.71 (s, 6H)	786.52	785.32
29	8.84 (s, 1H), 8.21 (d, 1H), 7.95-7.88 (m, 5H), 7.73 (d, 2H), 7.59-7.32 (m, 23H), 7.31-7.11 (m, 5H), 6.92 (d, 1H)	767.15	766.28
32	8.83 (s, 1H), 8.21-8.15 (m, 2H), 8.07-7.88 (m, 5H), 7.79-7.48 (m, 18H), 7.39-7.18 (m, 6H), 6.97 (d, 1H)	709.34	708.23
39	8.85 (s, 1H), 8.21 (d, 1H), 7.95-7.88 (m, 5H), 7.78-7.72 (m, 9H), 7.59-7.49 (m, 9H), 7.41-7.18 (m, 7H), 6.96 (d, 1H)	709.37	708.23
42	8.84 (s, 1H), 8.21 (d, 1H), 7.95-7.88 (m, 3H), 7.73 (d, 2H), 7.63-7.52 (m, 9H), 7.40-7.18 (m, 7H), 6.96 (d, 1H)	509.33	508.19
48	8.41 (d, 2H), 7.74 (d, 2H), 7.51 (d, 2H), 7.32 (d, 2H), 7.25-6.91 (m, 11H), 6.83 (d, 2H), 6.75 (d, 1H), 1.71 (s, 6H)	553.32	552.23
51	7.73-7.65 (m, 4H), 7.37-6.92 (m, 19H), 6.79 (d, 1H), 1.71 (s, 6H)	583.39	582.21
60	8.84 (s, 1H), 8.51 (s, 1H), 8.19 (d, 1H), 8.05 (d, 1H), 7.95-7.88 (m, 5H), 7.77-7.48 (m, 11H), 7.38 (t, 2H), 7.26-7.20 (m, 3H), 6.99 (d, 1H)	625.27	624.19
71	7.91 (d, 2H), 7.78-7.74 (m, 7H), 7.55-7.48 (m, 7H), 7.41-7.35 (m, 4H), 7.25-6.99 (m, 23H), 6.75 (d, 1H), 1.67 (s, 6H)	850.11	849.32

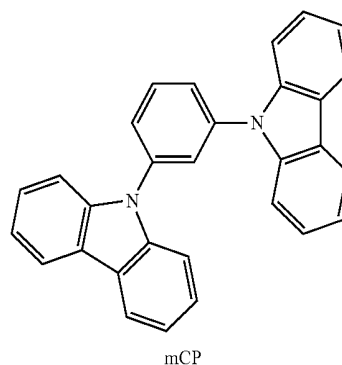
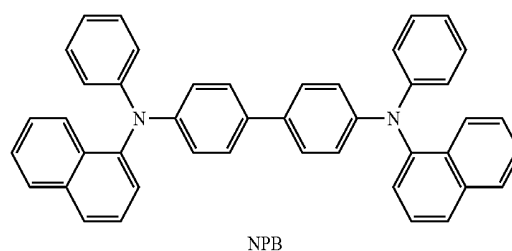
Example 1

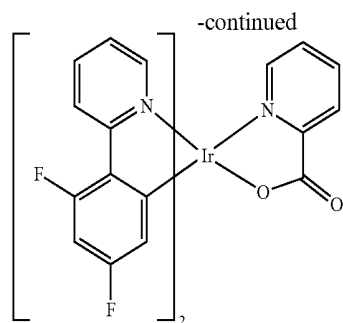
[0450] As a substrate and an anode, an ITO glass substrate (a product of Corning Co., Ltd) having a thickness of 15 Ω/cm² (1,200 Å) was cut to a size of 50 mm×50 mm×0.7 mm, sonicated by using isopropyl alcohol and pure water for about 5 minutes each, and cleaned by the exposure to ultraviolet rays for about 30 minutes, and then, ozone, and the resulting ITO glass substrate was mounted on a vacuum deposition apparatus.

[0451] NPD was vacuum deposited on the ITO glass substrate to form a hole injection layer having a thickness of about 300 Å, and then, mCP was vacuum deposited on the hole injection layer to form a hole transport layer having a thickness of about 200 Å. Thus, a hole transport region was formed.

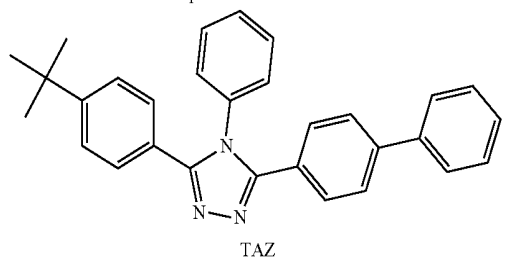
[0452] Compound 1 (as a host) and Flrpic (as a dopant) were co-deposited on the hole transport region at a weight ratio of 98:2 to form an emission layer having a thickness of about 250 Å.

[0453] TAZ was deposited on the emission layer to form an electron transport layer having a thickness of about 200 Å, and LiF was deposited on the electron transport layer to form an electron injection layer having a thickness of 10 Å. Al was vacuum deposited on the electron injection layer to form a cathode having a thickness of about 100 Å. Thus, an organic light-emitting device was formed.

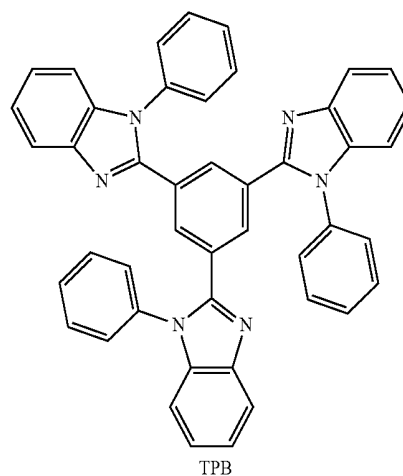




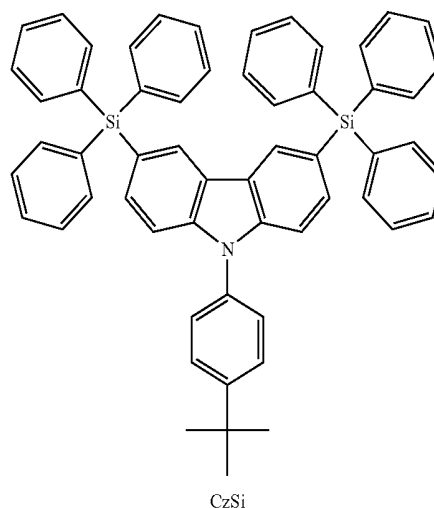
Irpic



TAZ



TPB



CzSi

Examples 2 to 7 and Comparative Example 1

[0454] Organic light-emitting devices were each manufactured in substantially the same manner as in Example 1, except that compounds listed in Table 2 were used in forming the emission layer.

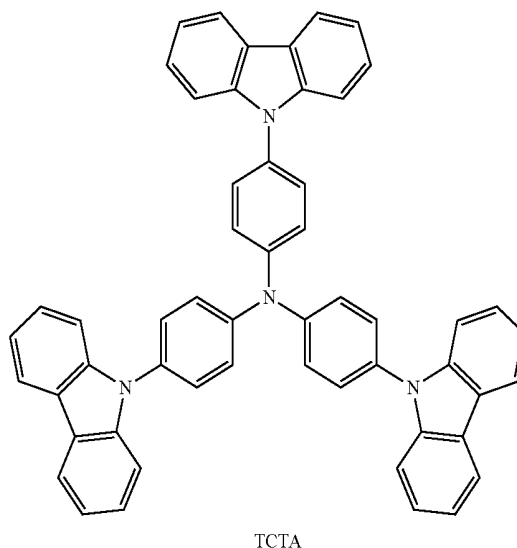
Example 8

[0455] As a substrate and an anode, an ITO glass substrate (a product of Corning Co., Ltd) having a thickness of 15 Ω/cm^2 (1,200 Å) was cut to a size of 50 mm×50 mm×0.7 mm, sonicated by using isopropyl alcohol and pure water for about 5 minutes each, and cleaned by the exposure to ultraviolet rays for about 30 minutes, and then, ozone, and the resulting ITO glass substrate was mounted on a vacuum deposition apparatus.

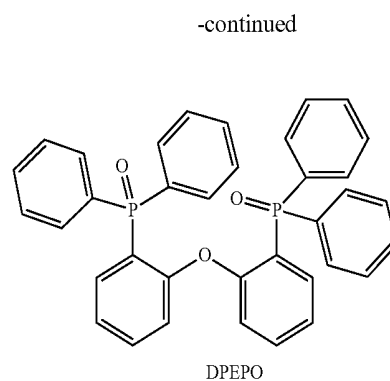
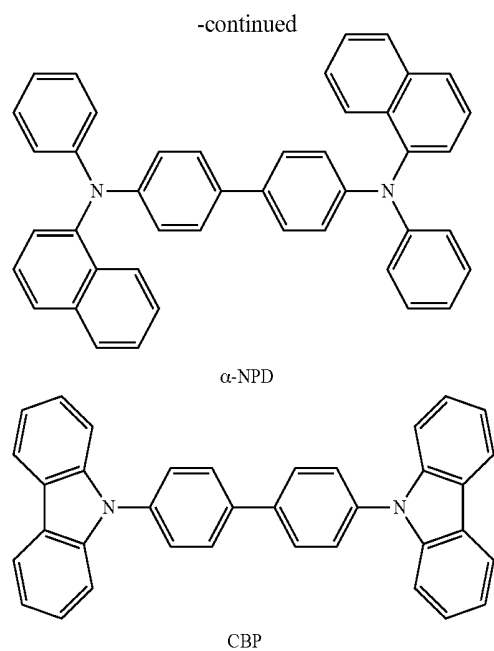
[0456] NPD was vacuum deposited on the ITO glass substrate to form a hole injection layer having a thickness of about 300 Å. TCTA was vacuum deposited on the hole injection layer to form a first hole transport layer having a thickness of about 200 Å, and then, CzSi was vacuum deposited on the first hole transport layer to form a second hole transport layer having a thickness of about 100 Å. Thus, a hole transport region was formed.

[0457] DPEPO (as a host) and Compound 19 (as a dopant) were co-deposited on the hole transport region at a weight ratio of 90:10 to form an emission layer having a thickness of about 200 Å.

[0458] DPEPO was deposited on the emission layer to form a first electron transport layer having a thickness of about 200 Å, and TPBI was deposited on the first electron transport layer to form a second electron transport layer having a thickness of about 300 Å. LiF was deposited on the second electron transport layer to form an electron injection layer having a thickness of 10 Å, and Al was vacuum deposited on the electron injection layer to form a cathode having a thickness of 3,000 Å. Thus, an organic light-emitting device was formed.



TCTA



Examples 8 to 14 and Comparative Example 2

[0459] Organic light-emitting devices were each manufactured in substantially the same manner as in Example 7, except that compounds listed in Table 2 were used in forming the emission layer.

TABLE 2

Host	Dopant	Driving voltage (V)	Current density (mA/cm ²)	Efficiency (cd/A)	Maximum quantum efficiency (%)	Emission color	
Example 1	1	Flrpic	4.1	2.65	15.1	24.1	Blue
Example 2	5	Flrpic	4.3	2.65	17.3	23.2	Blue
Example 3	6	Flrpic	4.2	2.65	18.1	22.5	Blue
Example 4	9	Flrpic	3.8	2.65	13.8	21.9	Blue
Example 5	32	Flrpic	3.9	2.65	14.1	22.3	Blue
Example 6	39	Flrpic	3.7	2.65	17.3	22.1	Blue
Example 7	42	Flrpic	4.2	2.65	14.5	20.1	Blue
Example 8	DPEPO	19	6.1	2.65	13.8	22.4	Blue
Example 9	DPEPO	29	6.0	2.65	14.1	21.9	Blue
Example 10	DPEPO	42	6.2	2.65	15.1	23.8	Blue
Example 11	DPEPO	48	5.5	2.65	17.0	24.1	Blue
Example 12	DPEPO	51	5.7	2.65	14.8	22.8	Blue
Example 13	DPEPO	60	5.9	2.65	15.9	24.3	Blue
Example 14	DPEPO	71	6.0	2.65	18.1	21.8	Blue
Comparative Example 1	CFP	Flrpic	4.9	2.65	11.2	16.1	Blue
Comparative Example 2	DPEPO	DPS	6.7	2.65	12.3	17.3	Blue
Comparative Example 3	CE3	Firpic	4.7	2.65	10.5	16.6	Blue
Comparative Example 4	CE4	Firpic	5.5	2.65	11.5	16.8	Blue
Comparative Example 5	CE5	Firpic	5.1	2.65	11.4	17.0	Blue

TABLE 2-continued

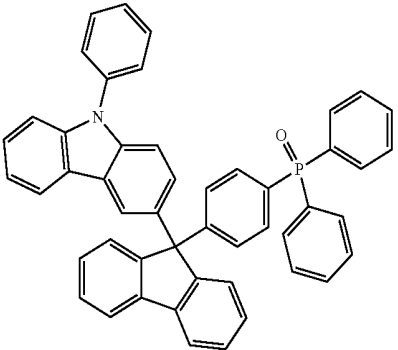
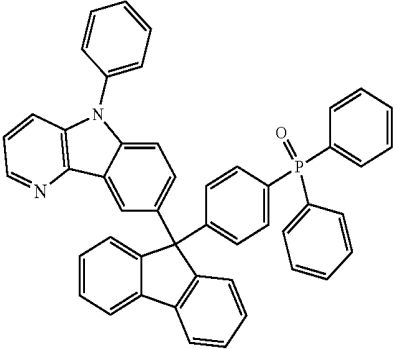
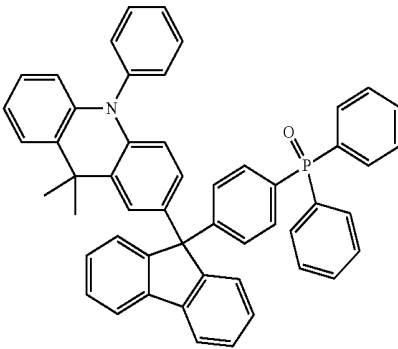
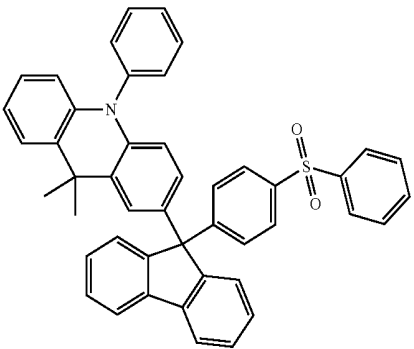
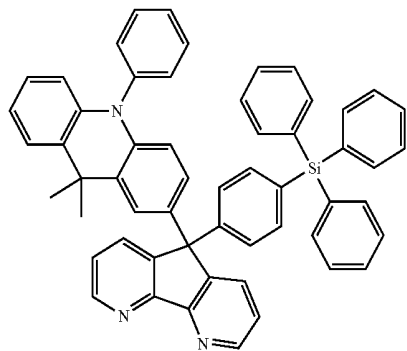
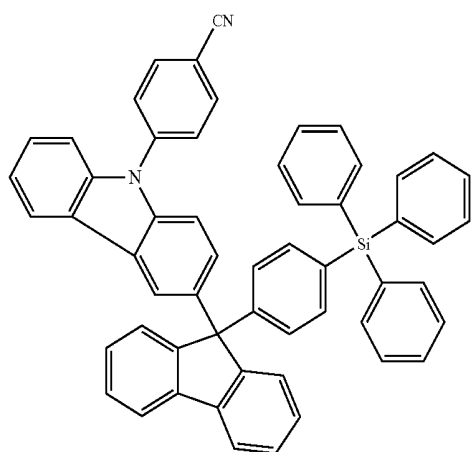
Host	Dopant	Driving voltage (V)	Current density (mA/cm ²)	Efficiency (cd/A)	Maximum quantum efficiency (%)	Emission color
						
						
						
						

TABLE 2-continued

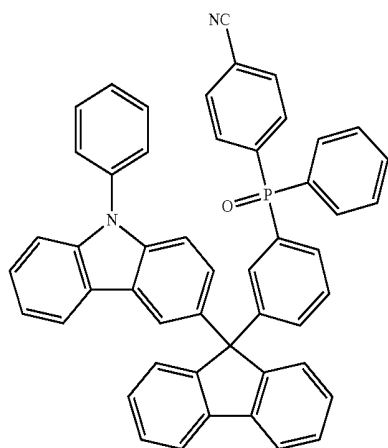
Host	Dopant	Driving voltage (V)	Current density (mA/cm ²)	Efficiency (cd/A)	Maximum quantum efficiency (%)	Emission color
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19



29



32

TABLE 2-continued

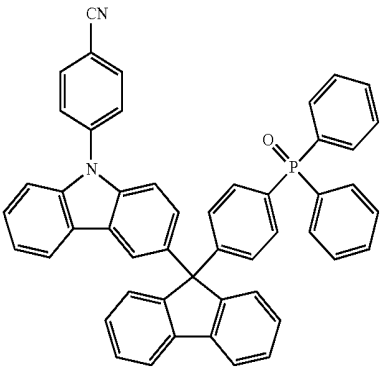
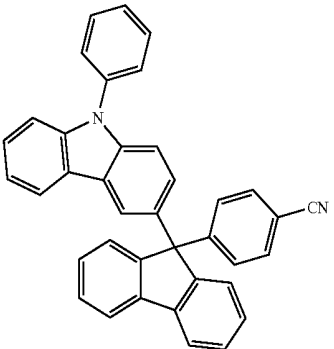
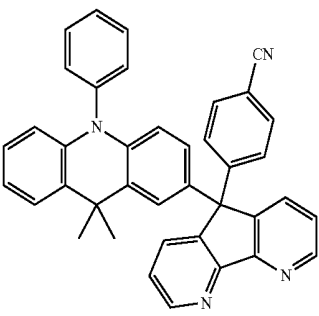
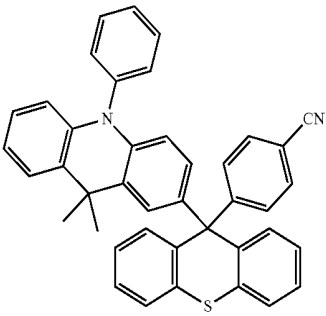
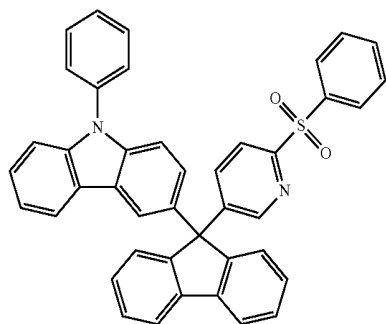
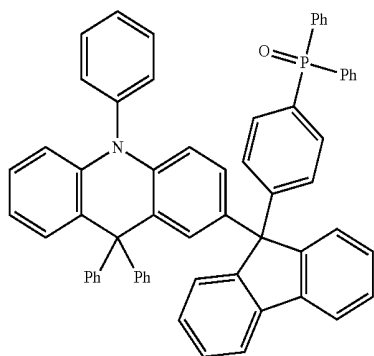
Host	Dopant	Driving voltage (V)	Current density (mA/cm ²)	Efficiency (cd/A)	Maximum quantum efficiency (%)	Emission color
						
39						
						
42						
						
48						
						
51						

TABLE 2-continued

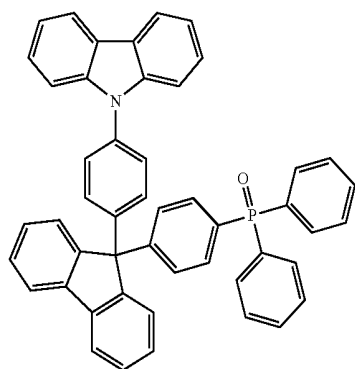
Host	Dopant	Driving voltage (V)	Current density (mA/cm ²)	Efficiency (cd/A)	Maximum quantum efficiency (%)	Emission color
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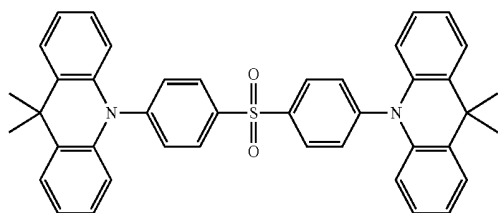
80



71

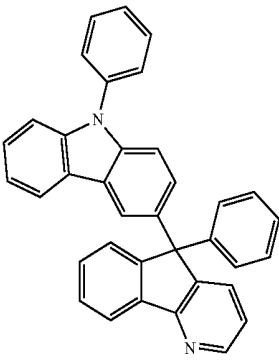
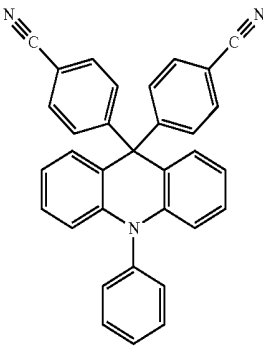
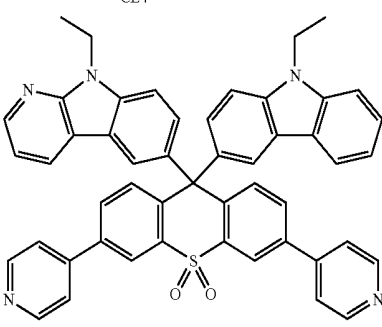


CFP



DPS

TABLE 2-continued

Host	Dopant	Driving voltage (V)	Current density (mA/cm ²)	Efficiency (cd/A)	Maximum quantum efficiency (%)	Emission color
						 CE3
						 CE4
						 CE5

[0460] Referring to Table 2, the organic light-emitting devices of Examples 1 to 14 had relatively low driving voltage, high efficiency, and high maximum quantum efficiency, compared to those of the organic light-emitting devices of Comparative Examples 1 to 5

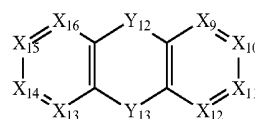
[0461] As described above, an organic light-emitting device including the condensed cyclic compound represented by Formula 1 may have a relatively low driving voltage and a relatively high efficiency.

[0462] 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.

[0463] While one or more embodiments have been described with reference to the figures, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope as defined by the following claims

What is claimed is:

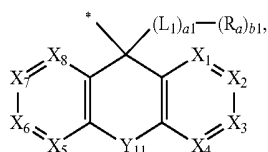
1. A condensed cyclic compound represented by Formula 1:



<Formula 1>

-continued

<Formula 2>



wherein, in Formulae 1 and 2,

X_1 is C(R_1) or N, X_2 is C(R_2) or N, X_3 is C(R_3) or N, X_4 is C(R_4) or N, X_5 is C(R_5) or N, X_6 is C(R_6) or N, X_7 is C(R_7) or N, X_8 is C(R_8) or N, X_9 is C(R_9), N, or C combined with a group represented by Formula 2, X_{10} is C(R_{10}), N, or C combined with a group represented by Formula 2, X_{11} is C(R_{11}), N, or C combined with a group represented by Formula 2, X_{12} is C(R_{12}), N, or C combined with a group represented by Formula 2, X_{13} is C(R_{13}) or N, X_{14} is C(R_{14}) or N, X_{15} is C(R_{15}) or N, X_{16} is C(R_{16}) or N, and at least one selected from X_9 to X_{12} is C combined with a group represented by Formula 2,

Y_{11} is selected from a single bond, a C(R_{21})(R_{22}), Si(R_{21})(R_{22}), O, S, P(=O)(R_{21}), S(=O), S(=O)₂, and N(R_{21}),

Y_{12} is selected from a single bond, a C(R_{23})(R_{24}), Si(R_{23})(R_{24}), O, S, P(=O)(R_{23}), S(=O), S(=O)₂, and N(R_{23}),

Y_{13} is selected from a single bond, a C(R_{25})(R_{26}), Si(R_{25})(R_{26}), O, S, P(=O)(R_{25}), S(=O), S(=O)₂, and N(R_{25}),

L_1 is a substituted or unsubstituted C₃-C₆₀ carbocyclic group or a substituted or unsubstituted C₁-C₆₀ heterocyclic group,

a_1 is an integer of 1 to 3, wherein, when a_1 is 2 or greater, at least two L_1 (s) are the same as or different from each other,

R_a is selected from a cyano group, —Si(Ar_1)(Ar_2)(Ar_3), —S(=O)₂(Ar_1), and —P(=O)(Ar_1)(Ar_2),

b_1 is an integer of 1 to 3, wherein, when b_1 is 2 or greater, at least two R_a (s) are the same as or different from each other,

when R_a is —Si(Ar_1)(Ar_2)(Ar_3), —S(=O)₂(Ar_1), or —P(=O)(Ar_1)(Ar_2), L_1 and Ar_1 are optionally linked to each other to form a ring,

Ar_1 and Ar_2 are optionally linked to each other to form a ring,

Ar_1 to Ar_3 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 C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic

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

R_1 to R_{16} and R_{21} to R_{26} 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 C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(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), at least one substituent of the substituted C₃-C₆₀ carbocyclic group, the substituted C₁-C₆₀ heterocyclic group, the substituted C₁-C₆₀ alkyl group, the substituted C₂-C₆₀ alkenyl group, the substituted C₂-C₆₀ alkynyl group, the substituted C₁-C₆₀ alkoxy group, the substituted C₃-C₁₀ cycloalkyl group, the substituted C₁-C₁₀ heterocycloalkyl group, the substituted C₃-C₁₀ cycloalkenyl group, the substituted C₁-C₁₀ heterocycloalkenyl group, the substituted C₆-C₆₀ aryl group, the substituted C₆-C₆₀ aryloxy group, the substituted C₆-C₆₀ arylthio group, the substituted C₁-C₆₀ heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group is selected from:

deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino 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 amino group, an amidino group, a hydrazino group, a hydrazono group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —Si(Q_{11})(Q_{12})(Q_{13}), —N(Q_{11})(Q_{12}), —B(Q_{11})(Q_{12}), —C(=O)(Q_{11}), —S(=O)₂(Q_{11}), and —P(=O)(Q_{11})(Q_{12});

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 het-

eroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group;

- a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a 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 biphenyl group, a terphenyl 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 amino 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, and indicates a binding site to a neighboring atom.

2. The condensed cyclic compound of claim 1, wherein R₁ to R₁₆ are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C₁-C₂₀ alkyl group, and a C₁-C₂₀ alkoxy group.

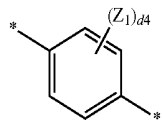
3. The condensed cyclic compound of claim 1, wherein R₂₁ to R₂₆ are each independently selected from:

hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C₁-C₂₀ alkyl group and a C₁-C₂₀ alkoxy group;

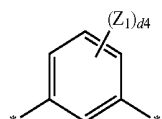
a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group; and

a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, and a nitro group.

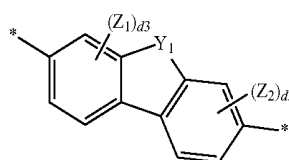
4. The condensed cyclic compound of claim 1, wherein L₁ is selected from groups represented by Formulae 3-1 to 3-49:



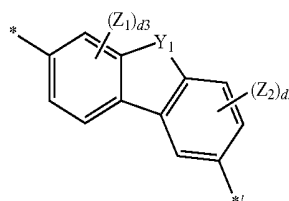
Formula 3-1



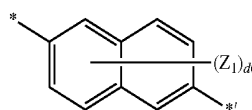
Formula 3-2



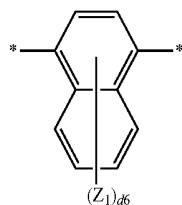
Formula 3-3



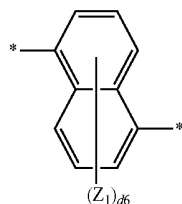
Formula 3-4



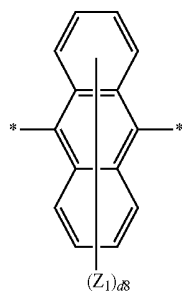
Formula 3-5



Formula 3-6

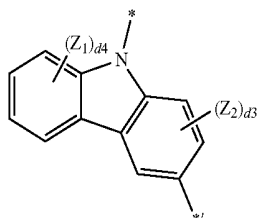
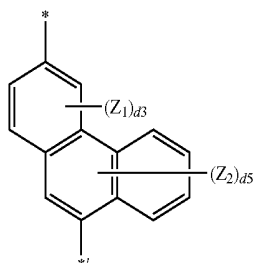
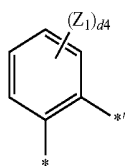
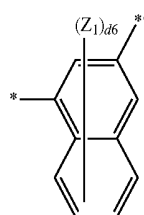
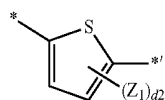
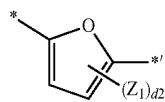
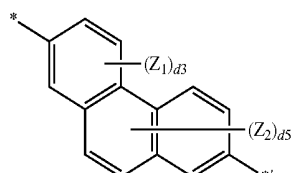
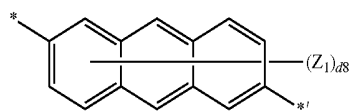


Formula 3-7



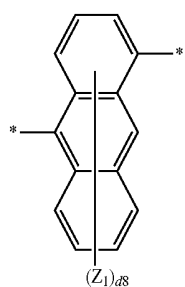
Formula 3-8

-continued

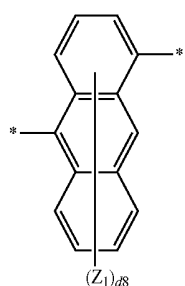


-continued

Formula 3-9

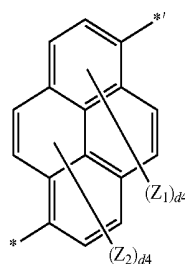


Formula 3-10



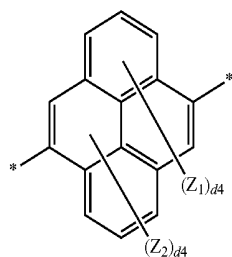
Formula 3-11

Formula 3-12



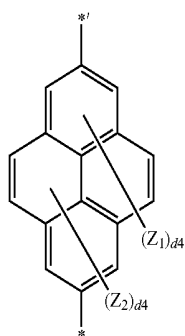
Formula 3-13

Formula 3-14



Formula 3-15

Formula 3-16



Formula 3-17

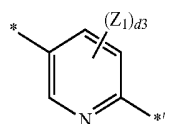
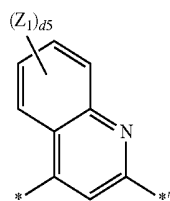
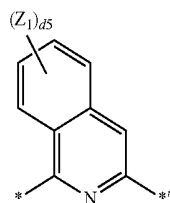
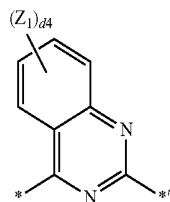
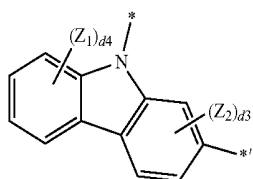
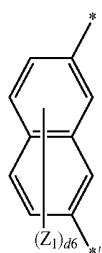
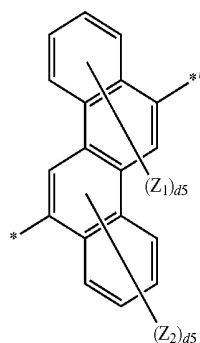
Formula 3-18

Formula 3-19

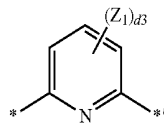
Formula 3-20

Formula 3-21

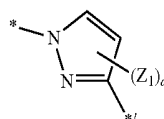
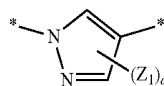
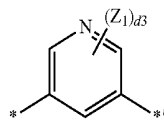
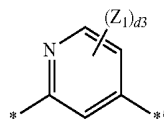
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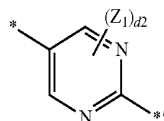
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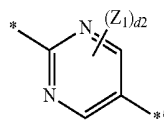
Formula 3-23



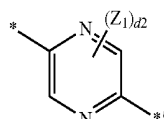
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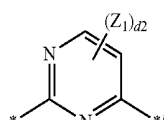
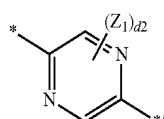
Formula 3-25



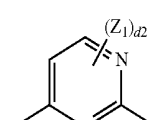
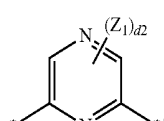
Formula 3-26



Formula 3-27



Formula 3-28



-continued

Formula 3-29

Formula 3-30

Formula 3-31

Formula 3-32

Formula 3-33

Formula 3-34

Formula 3-35

Formula 3-36

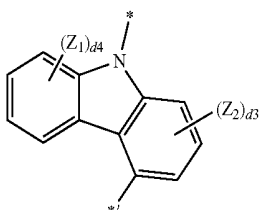
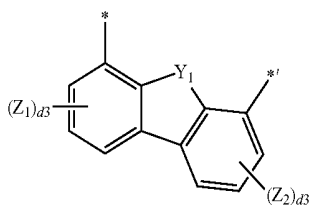
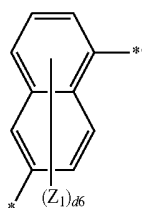
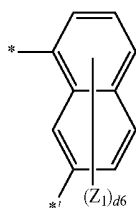
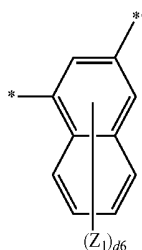
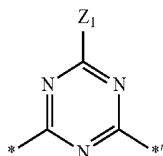
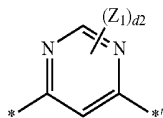
Formula 3-37

Formula 3-38

Formula 3-39

Formula 3-40

-continued



Formula 3-41

Formula 3-42

Formula 3-43

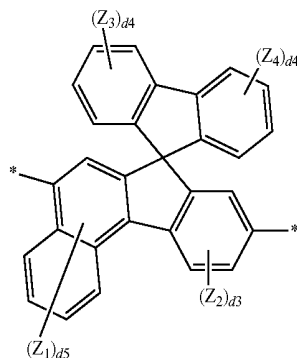
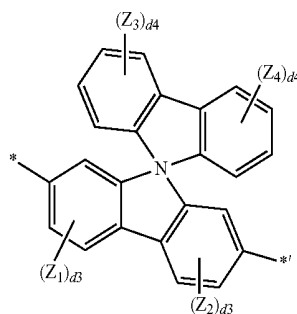
Formula 3-44

Formula 3-45

Formula 3-46

Formula 3-47

-continued



Formula 3-48

Formula 3-49

wherein, in Formulae 3-1 to 3-49,

Y_1 is O, S, $C(Z_5)(Z_6)$, $N(Z_5)$, or $Si(Z_5)(Z_6)$,

Z_1 to Z_6 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 C_1 - C_{20} alkyl group, a C_1 - C_{20} alkenyl group, a C_1 - C_{20} alkynyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, $-Si(Q_{31})(Q_{32})(Q_{33})$, $-N(Q_{31})(Q_{32})$, $-B(Q_{31})(Q_{32})$, $-C(=O)(Q_{31})$, $-S(=O)_2(Q_{31})$, and $-P(=O)(Q_{31})(Q_{32})$,

Q_{31} to Q_{33} are each independently 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,

d_2 is 1 or 2,

d_3 is an integer of 1 to 3,

d_4 is an integer of 1 to 4,

d_5 is an integer of 1 to 5,

d_6 is an integer of 1 to 6,

d_8 is an integer of 1 to 8, and

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

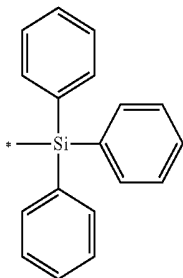
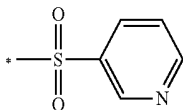
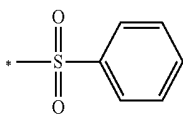
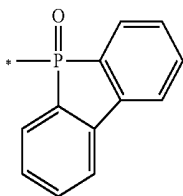
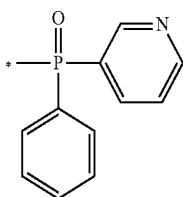
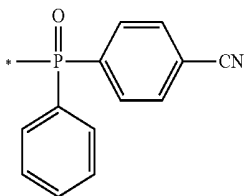
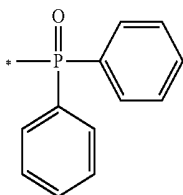
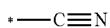
5. The condensed cyclic compound of claim 1, wherein a_1 is 1.

6. The condensed cyclic compound of claim 1, wherein Ar_1 to Ar_n are each independently selected from:

a phenyl group, a biphenyl group, a terphenyl group, a pyridinyl group, and a pyrimidinyl group; and

a phenyl group, a biphenyl group, a terphenyl group, a pyridinyl group, and a pyrimidinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, and a nitro group.

7. The condensed cyclic compound of claim 1, wherein R_a is selected from groups represented by Formulae 5A to 5H:



wherein, * indicates a binding site to a neighboring atom.

8. The condensed cyclic compound of claim 1, wherein b1 is 1 or 2,

wherein, when b1 is 2 or greater, at least two R_a (s) are the same as or different from each other.

9. The condensed cyclic compound of claim 1, wherein R_1 to R_{16} are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group, and

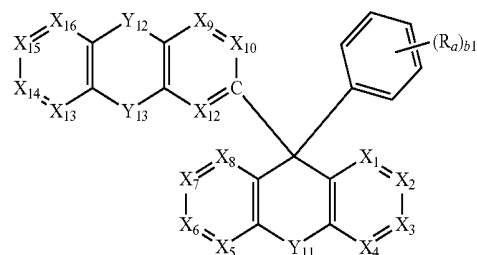
R_{21} to R_{26} are each independently selected from:

a methyl group, an ethyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and a pyridinyl group; and

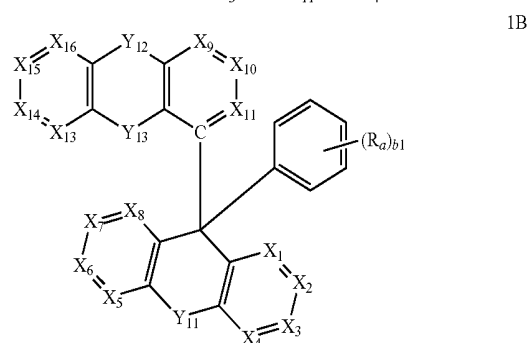
a phenyl group substituted with a cyano group.

10. The condensed cyclic compound of claim 1, wherein the compound represented by Formula 1 is represented by one selected from Formulae 1A to 1H:

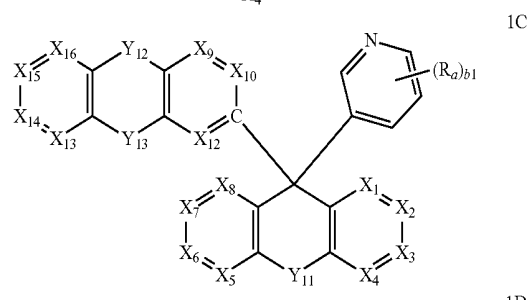
5C



5D



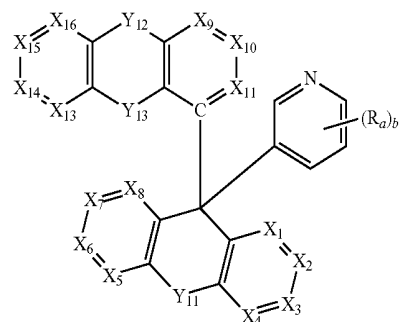
5E



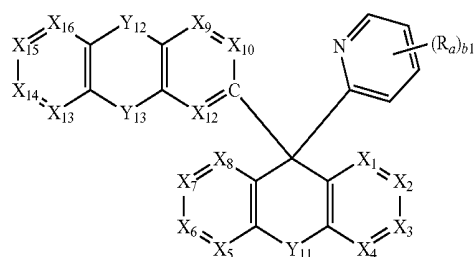
5F

5G

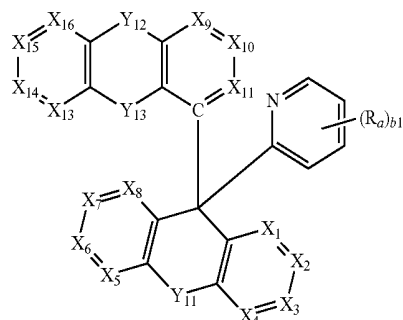
5H



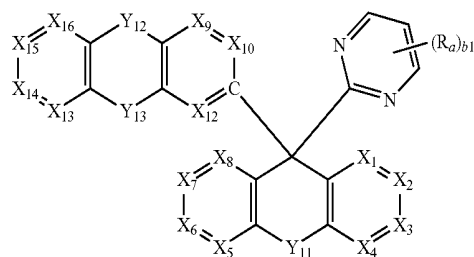
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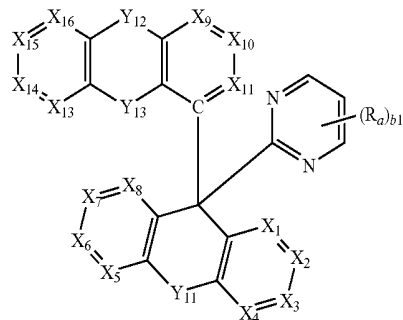
1E



1F



1G



1H

wherein, in Formulae 1A to 1H, X_1 to X_{16} , Y_{11} to Y_{13} , R_a , and b_1 are each independently the same as in claim 1.

11. The condensed cyclic compound of claim 10, wherein X_1 is $C(R_1)$ or N, X_2 is $C(R_2)$ or N, X_3 is $C(R_3)$ or N, X_4 is $C(R_4)$ or N, X_5 is $C(R_5)$ or N, X_6 is $C(R_6)$ or N, X_7 is $C(R_7)$ or N, X_8 is $C(R_8)$ or N, X_9 is $C(R_9)$ or N, X_{10} is $C(R_{10})$ or N, X_{11} is $C(R_{11})$ or N, X_{12} is $C(R_{12})$ or N, X_{13} is $C(R_{13})$ or N, X_{14} is $C(R_{14})$ or N, X_{15} is $C(R_{15})$ or N, and X_{16} is $C(R_{16})$ or N,

R_1 to R_{16} are each independently hydrogen or a cyano group,

Y_{11} is selected from a single bond, a $C(R_{21})(R_{22})$, $Si(R_{21})(R_{22})$, O, S, $P(=O)(R_{21})$, $S(=O)$, $S(=O)_2$, and $N(R_{21})$,

Y_{12} is selected from a single bond, a $C(R_{23})(R_{24})$, $Si(R_{23})(R_{24})$, O, S, $P(=O)(R_{23})$, $S(=O)$, $S(=O)_2$, and $N(R_{23})$,

Y_{13} is selected from a single bond, a $C(R_{25})(R_{26})$, $Si(R_{25})(R_{26})$, O, S, $P(=O)(R_{25})$, $S(=O)$, $S(=O)_2$, and $N(R_{25})$,

R_{21} to R_{26} are each independently selected from: a methyl group, a phenyl group, and a pyridinyl group; and

a phenyl group substituted with a cyano group, R_a is selected from a cyano group, $-Si(Ar_1)(Ar_2)(Ar_3)$, $-S(=O)_2(Ar_1)$, and $-P(=O)(Ar_1)(Ar_2)$,

Ar_1 to Ar_3 are each independently selected from:

a phenyl group and a pyridinyl group; and a cyano group a phenyl group substituted with a cyano group, and b_1 is 1 or 2.

12. An organic light-emitting device comprising:

a first electrode;

a second electrode facing the first electrode; and

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

wherein the organic layer comprises at least one condensed cyclic compound represented by Formula 1 of claim 1.

13. The organic light-emitting device of claim 12, wherein the first electrode is an anode,

the second electrode is a cathode,

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

wherein the hole transport region comprises a hole injection layer, a hole transport layer, an emission auxiliary layer, an electron blocking layer, or any combination thereof, and the electron transport region comprises a buffer layer, a hole blocking layer, an electron control layer, an electron transport layer, an electron injection layer, or any combination thereof.

14. The organic light-emitting device of claim 12, wherein the emission layer comprises a dopant and a host, the dopant comprising the at least one condensed cyclic compound represented by Formula 1 of claim 1.

15. The organic light-emitting device of claim 14, wherein the host in the emission layer comprises at least one selected from an anthracene-based compound, a pyrene-based compound, and a spiro-bifluorene-based compound.

16. The organic light-emitting device of claim 12, wherein the emission layer comprises a dopant and a host, the host comprising the at least one condensed cyclic compound represented by Formula 1 of claim 1.

17. The organic light-emitting device of claim 16, wherein the dopant in the emission layer comprises at least one of a styryl-based compound and an amine-based compound.

18. The organic light-emitting device of claim 13, wherein the hole transport region comprises a p-dopant, wherein a lowest unoccupied molecular orbital (LUMO) of the p-dopant is about -3.5 eV or less.

19. The organic light-emitting device of claim 13, wherein the electron transport region comprises 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.

20. The organic light-emitting device of claim 12, wherein the emission layer is a first color light-emitting layer, the organic light-emitting device further comprises, between the first electrode and the second electrode, i) at least one second color light-emitting layer or ii) at least one second color light-emitting layer and at least one third color light-emitting layer, a maximum emission wavelength of the first color light-emitting layer, a maximum emission wavelength of the second color light-emitting layer, and a maximum emission wavelength of the third color light-emitting layer are the same as or different from each other, and the first color light and the second color light are emitted in the form of mixed light, or the first color light, the second color light, and the third color light are emitted in the form of mixed light.

* * * * *

专利名称(译)	缩合环状化合物和包括其的有机发光器件		
公开(公告)号	US20180269404A1	公开(公告)日	2018-09-20
申请号	US15/714652	申请日	2017-09-25
[标]申请(专利权)人(译)	三星显示有限公司		
申请(专利权)人(译)	三星DISPLAY CO. , LTD.		
当前申请(专利权)人(译)	三星DISPLAY CO. , LTD.		
[标]发明人	AHN HEECHOON KO SOOBYUNG JUN MIEUN KIM YOUNGKOOK HWANG SEOKHWAN		
发明人	AHN, HEECHOON KO, SOOBYUNG JUN, MIEUN KIM, YOUNGKOOK HWANG, SEOKHWAN		
IPC分类号	H01L51/00 H01L51/50 H01L51/52		
CPC分类号	H01L51/0069 H01L51/5092 H01L51/5072 H01L51/506 H01L51/5036 H01L51/5068 H01L51/5221 H01L51/5206 H01L51/0071 H01L51/0052 H01L51/0067 H01L51/0072 H01L51/0094 H01L51/5012 H01L51/5016		
优先权	1020160123384 2016-09-26 KR		
外部链接	Espacenet USPTO		

摘要(译)

提供缩合环状化合物和包含其的有机发光装置。稠环化合物可由式1表示：其中X_i可以是C(R_i)或N或包括式2的取代基，其中i是整数：提供了关于式1和式2的结构进一步细节。

