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

(71) Applicant: **SAMSUNG DISPLAY CO., LTD.**, Yongin-si, Gyeonggi-do (KR)

(72) Inventors: **Junha Park**, Yongin-si (KR); **Youngkook Kim**, Yongin-si (KR); **Munki Sim**, Yongin-si (KR); **Hyoyoung Lee**, Yongin-si (KR); **Eunjae Jeong**, Yongin-si (KR); **Seokhwan Hwang**, Yongin-si (KR)

(73) Assignee: **SAMSUNG DISPLAY CO., LTD.**, Yongin-si, Gyeonggi-Do (KR)

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None
See application file for complete search history.

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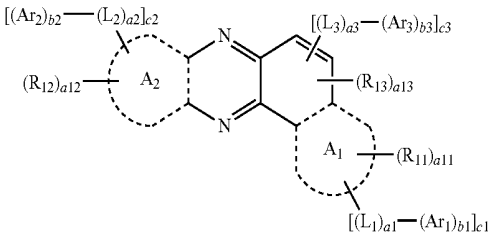
Primary Examiner — Jay Yang
(74) *Attorney, Agent, or Firm* — F. Chau & Associates, LLC

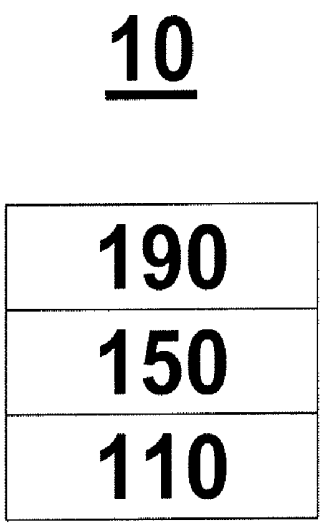
(57) **ABSTRACT**

A condensed cyclic compound represented by Formula 1 and an organic light-emitting device including the same.

[Formula 1]



17 Claims, 4 Drawing Sheets



(51) **Int. Cl.**

C07D 403/04	(2006.01)
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C07D 409/10	(2006.01)
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C07F 9/6558	(2006.01)
C09K 11/06	(2006.01)
C07D 401/14	(2006.01)
C07D 401/10	(2006.01)
C07D 405/10	(2006.01)
H01L 51/50	(2006.01)

(52) **U.S. Cl.**

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FIG. 1

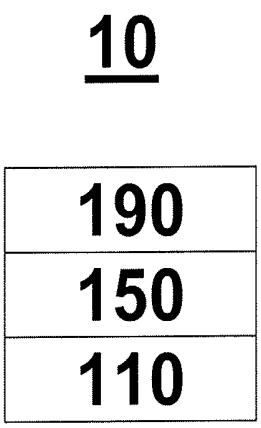


FIG. 2

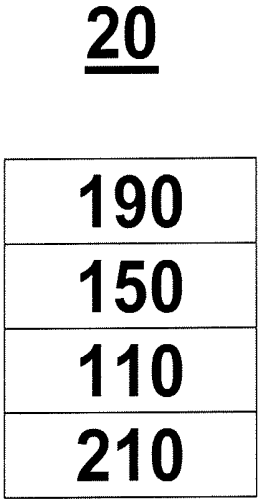


FIG. 3

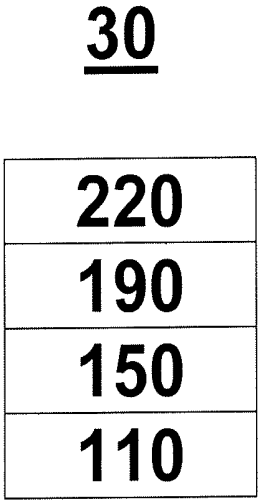
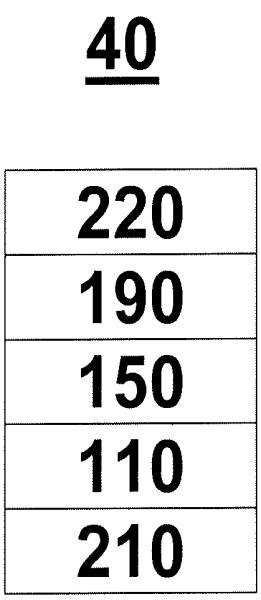


FIG. 4



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

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of Korean Patent Application No. 10-2016-0076609, filed on Jun. 20, 2016 in the Korean Intellectual Property Office, the disclosure of which is incorporated by reference herein in its entirety.

TECHNICAL FIELD

Exemplary embodiments of the present invention relate to a condensed cyclic compound, and more particularly to an organic light-emitting device including the same.

DISCUSSION OF RELATED ART

Organic light-emitting devices may be self-emission devices. Organic light-emitting devices may have relatively wide viewing angles, relatively high contrast ratios, relatively short response times, and increased brightness, driving voltage, and response speed characteristics. Organic light-emitting devices may produce full-color images.

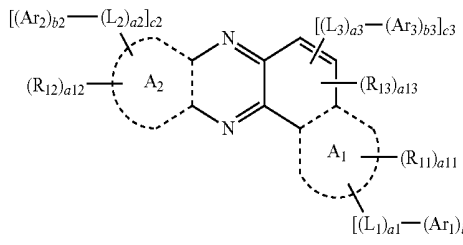
Organic light-emitting devices may include a first electrode disposed on a substrate. Organic light-emitting devices may further include a hole transport region, an emission layer, an electron transport region, and a second electrode, sequentially disposed on the first electrode. Holes provided from the first electrode may move toward the emission layer through the hole transport region. Electrons provided from the second electrode may move toward the emission layer through the electron transport region. Carriers, such as holes and electrons, may recombine in the emission layer to produce excitons. The excitons may transition from an excited state to a ground state, thus generating light.

SUMMARY

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

One or more exemplary embodiments provide a condensed cyclic compound. The condensed cyclic compound is represented by Formula 1:

<Formula 1>



A_1 and A_2 in Formula 1 are each independently be selected from a benzene group, a naphthalene group, a quinoline group, an isoquinoline group, or a quinazoline group,

L_1 to L_3 in Formula 1 are each independently 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, a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group, *—P(=O)(Q_4)-*', *—P(=S)(Q_4)-*', *—S(=O)—*', or *—S(=O)$_2$—*',

a1 to a3 in Formula 1 are each independently be an integer selected from 0 to 7. When a1 is 2 or greater, at least two L_1(s) are the same or different from each other. When a2 is two or greater, at least two or more L_2(s) are the same or different from each other. When a3 is 2 or greater, at least two L_3(s) are the same or different from each other.

Ar_1 to Ar_3 in Formula 1 are each independently selected from a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —S(=O)$_2$(Q_4), —P(=O)(Q_4)(Q_5), —P(=S)(Q_4)(Q_5), or —S(=O)(Q_4).

b1 to b3 in Formula 1 are each independently an integer selected from 1 to 7. When b1 is 2 or greater, at least two Ar_1(s) are the same or different from each other. When b2 is 2 or greater, at least two Ar_2(s) are the same or different from each other. When b3 is 2 or greater, at least two Ar_3(s) are the same or different from each other.

c1 and c3 in Formula 1 are each independently an integer selected from 0 to 6, and c2 is an integer selected from 0 to 2.

c1 to c3 satisfy the formula of c1+c2+c3≥1.

R_{11}, R_{12}, and R_{13} in Formula 1 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, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(Q_1)(Q_2)(Q_3), or —S(=O)$_2$(Q_1).

a11 and a12 in Formula 1 are each independently an integer selected from 0 to 6, and a13 is an integer selected from 0 to 2. When a11 is 2 or greater, at least two R_{11}(s) are the same or different from each other. When a12 is 2 or greater, at least two R_{12}(s) are the same or different from each other. When a13 is 2, two of R_{13}(s) are the same or different from each other.

At least one substituent selected from a substituent(s) of the substituted C_3-C_{10} cycloalkylene group, the substituted

C_1-C_{10} heterocycloalkylene group, the substituted C_3-C_{10} cycloalkenylene group, the substituted C_1-C_{10} heterocycloalkenylene group, the substituted C_6-C_{60} arylene group, the substituted C_1-C_{60} heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, the substituted divalent non-aromatic condensed heteropolycyclic group, the substituted C_1-C_{60} alkyl group, the substituted C_2-C_{60} alkenyl group, the substituted C_2-C_{60} alkynyl group, the substituted C_1-C_{60} alkoxy group, the substituted C_3-C_{10} cycloalkyl group, the substituted C_1-C_{10} heterocycloalkyl group, the substituted C_3-C_{10} cycloalkenyl group, the substituted C_1-C_{10} heterocycloalkenyl group, the substituted C_6-C_{60} aryl group, the substituted C_6-C_{60} aryloxy group, the substituted C_6-C_{60} arylthio group, the substituted C_1-C_{60} heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, or the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from:

deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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, or a substituted or unsubstituted C_1-C_{60} alkoxy group;

a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $—Si(Q_{11})(Q_{12})(Q_{13})$, $—N(Q_{11})(Q_{12})$, $—B(Q_{11})(Q_{12})$, $—C(=O)(Q_{11})$, $—S(=O)_2(Q_{11})$, or $—P(=O)(Q_{11})(Q_{12})$;

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

a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic 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 C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $—Si(Q_{21})(Q_{22})(Q_{23})$, $—N(Q_{21})(Q_{22})$, $—B(Q_{21})(Q_{22})$, $—C(=O)(Q_{21})$, $—S(=O)_2(Q_{21})$, or $—P(=O)(Q_{21})(Q_{22})$; and

$—Si(Q_{31})(Q_{32})(Q_{33})$, $—N(Q_{31})(Q_{32})$, $—B(Q_{31})(Q_{32})$, $—C(=O)(Q_{31})$, $—S(=O)_2(Q_{31})$, or $—P(=O)(Q_{31})(Q_{32})$.

Q_1 to Q_5, Q_{11} to Q_{13}, Q_{21} to Q_{23}, and Q_{31} to Q_{33} 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_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, or a terphenyl group.

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

One or more exemplary embodiments of the present invention provide an organic light-emitting device. The organic light-emitting device includes 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 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

The above and other features of the present invention will become more apparent by describing in detail exemplary embodiments thereof, with reference to the accompanying drawings, in which:

FIG. **1** is a schematic cross-sectional diagram illustrating an organic light-emitting device according to an exemplary embodiment of the present invention;

FIG. **2** is a schematic cross-sectional diagram illustrating an organic light-emitting device according to an exemplary embodiment of the present invention;

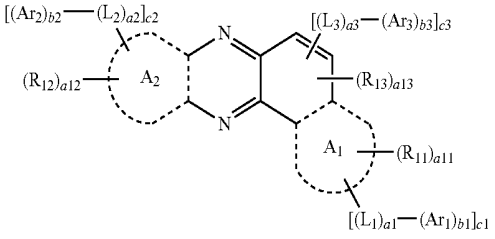
FIG. **3** is a schematic cross-sectional diagram illustrating an organic light-emitting device according to an exemplary embodiment of the present invention; and

FIG. **4** is a schematic cross-sectional diagram illustrating an organic light-emitting device according to an exemplary embodiment of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

One or more exemplary embodiments of the present invention provide a condensed cyclic compound. The condensed cyclic compound may be represented by Formula 1:

<Formula 1>



In Formula 1, A_1, A_2, L_1 to L_3, a1 to a3, Ar_1 to Ar_3, b1 to b3, c1 to c3, R_{11} to R_{13}, and a11 to a13 are substantially the same as described below.

A_1 and A_2 in Formula 1 may each independently be selected from a benzene group, a naphthalene group, a quinoline group, an isoquinoline group, or a quinazoline

group; however, exemplary embodiments of the present invention are not limited thereto. According to an exemplary embodiment of the present invention, A_1 and A_2 may each independently be selected from a benzene group or a naphthalene group. According to an exemplary embodiment of the present invention, A_1 and A_2 may both be a benzene group.

L_1 to L_3 in Formula 1 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, a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group, *—P(=O)(Q_4)-*', *—P(=S)(Q_4)-*', *—S(=O)—*', or *—S(=O)$_2$—*'; however, exemplary embodiments of the present invention are not limited thereto.

According to an exemplary embodiment of the present invention, L_1 to L_3 in Formula 1 may each independently be selected from:

a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene 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, a pyridinylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isoxazolylene group, a thiadiazolylene group, an oxadiazolylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, an isobenzothiazolylene group, a benzoxazolyiene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, or an azacarbazolylene group;

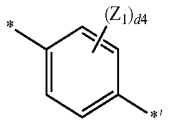
a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene 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 dibenzocarbazoiylene group, a dibenzosilolylene group, a pyridinylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isoxazolylene group, a thiadiazolylene group, an oxadiazolylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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, 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, or an azacarbazolyl group; and

—P(=O)(Q_4)-', *—P(=S)(Q_4)-*', *—S(=O)—*', or *—S(=O)$_2$—*'; however exemplary embodiments of the present invention are not limited thereto.

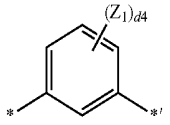
Q_4 may be selected from a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a pyridine, a pyrimidine, a pyrazine, or a naphthyl group; however, exemplary embodiments of the present invention are not limited thereto.

According to an exemplary embodiment of the present invention, L_1 to L_3 in Formula 1 may each independently be selected from groups represented by Formulae 2-1 to 2-35; however, exemplary embodiments of the present invention are not limited thereto.

Formula 2-1

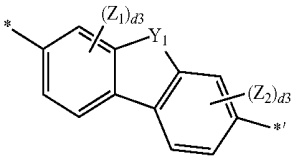


Formula 2-2

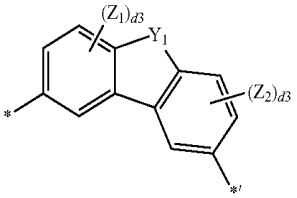


-continued

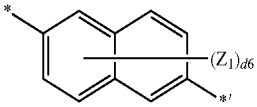
Formula 2-3



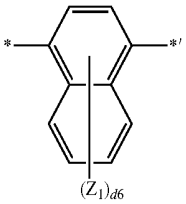
Formula 2-4



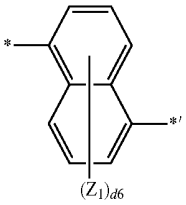
Formula 2-5



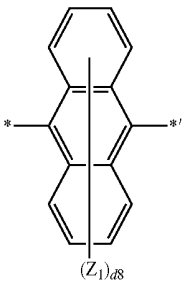
Formula 2-6



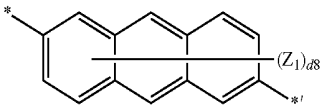
Formula 2-7



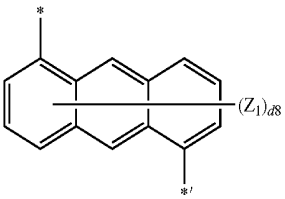
Formula 2-8



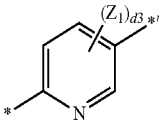
Formula 2-9



Formula 2-10



Formula 2-11



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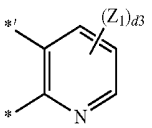
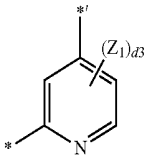
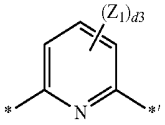
Formula 2-12



Formula 2-13



Formula 2-14



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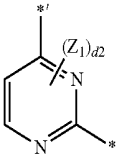
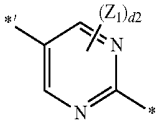
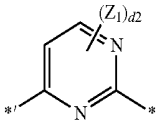


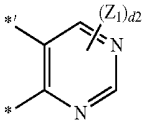
Formula 2-16



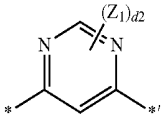
Formula 2-17



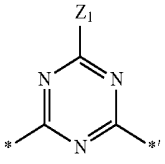
Formula 2-18



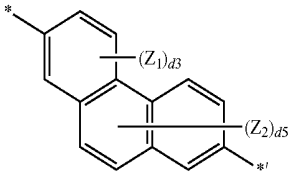
Formula 2-19



Formula 2-20



Formula 2-21



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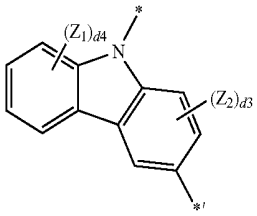

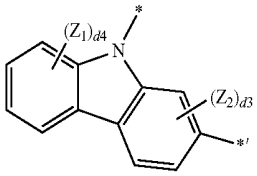

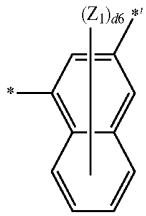

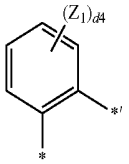

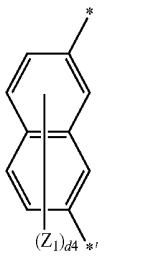

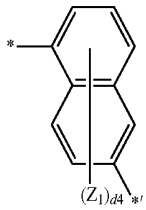

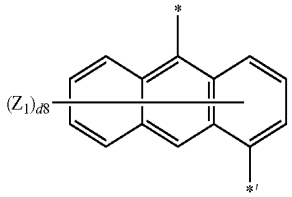

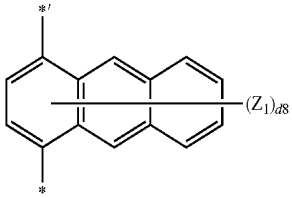

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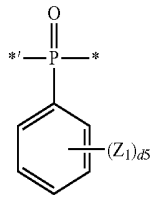
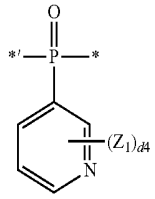
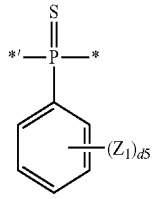
Formula 2-22



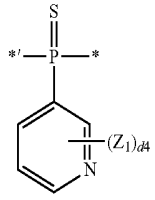
Formula 2-23



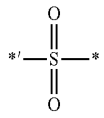
Formula 2-24



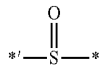
Formula 2-25



Formula 2-26



Formula 2-27



Formula 2-28

Formula 2-29

Formula 2-30

Formula 2-31

Formula 2-32

Formula 2-33

Formula 2-34

Formula 2-35

In Formulae 2-1 to 2-35:

Y_1 may be selected from O, S, $C(Z_3)(Z_4)$, $N(Z_5)$, or $Si(Z_6)(Z_7)$,

Z_1 to Z_7 may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-benzofluorene-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an indolyl group, an isoindolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, an isoquino-

linyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphthosilolyl group, a thiadiazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafluorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indenocarbazolyl group, or an indolocarbazolyl group,

d2 may be an integer selected from 0 to 2,

d3 may be an integer selected from 0 to 3,

d4 may be an integer selected from 0 to 4,

d5 may be an integer selected from 0 to 5,

d6 may be an integer selected from 0 to 6, and

d8 may be an integer selected from 0 to 8.

According to an exemplary embodiment of the present invention, L_1 to L_3 in Formula 1 may each independently be selected from groups represented by Formulae 2-1 to 2-3, 2-5, 2-8, 2-14, 2-17, 2-20, and 2-30 to 2-35.

a1 to a3 in Formula 1 may each independently be an integer selected from 0 to 7; however, exemplary embodiments of the present invention are not limited thereto. When a1 is 2 or greater, at least two L_1 (s) may be the same or different from each other. When a2 is 2 or greater, at least two L_2(s) may be the same or different from each other. When a3 is 2 or greater, at least two L_3(s) may be the same or different from each other.

According to an exemplary embodiment of the present invention, a1 to a3 in Formula 1 may each independently be an integer selected from 0, to 2; however, exemplary embodiments of the present invention are not limited thereto. For example, in Formula 1, a1 may be 0, a2 may be 0, and a3 may be an integer selected from 0 to 2.

Ar_1 to Ar_3 in Formula 1 may each independently be selected from a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —S(=O)$_2$(Q_4), —P(=O)(Q_4)(Q_5), —P(=S)(Q_4)(Q_5), or —S(=O)(Q_4); however, exemplary embodiments of the present invention are not limited thereto.

According to an exemplary embodiment of the present invention, Ar_1 to Ar_3 in Formula 1 may each independently be selected from:

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

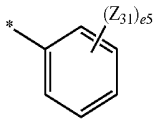
pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, 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, or an azacarbazolyl group; or

$—S(=O)_2(Q_4)$, $—P(=O)(Q_4)(Q_5)$, $—P(=S)(Q_4)(Q_5)$, or $—S(=O)(Q_4)$; however, exemplary embodiments of the present invention are not limited thereto.

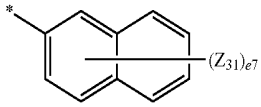
Q_4 and Q_5 may each independently be selected from a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a pyridine, a pyrimidine, a pyrazine, or a naphthyl group; however, exemplary embodiments of the present invention are not limited thereto.

According to an exemplary embodiment of the present invention, Ar_1 to Ar_3 in Formula 1 may each independently be selected from groups represented by Formulae 3-1 to 3-31; however, exemplary embodiments of the present invention are not limited thereto.

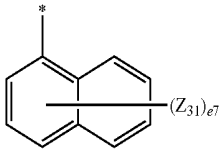
Formula 3-1



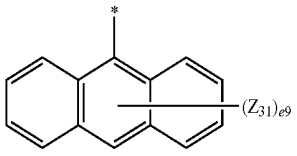
Formula 3-2



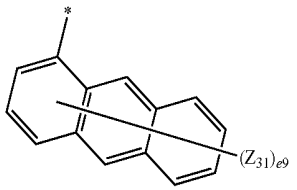
Formula 3-3



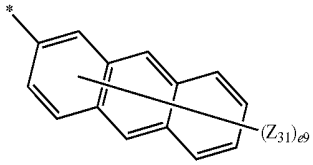
Formula 3-4



Formula 3-5

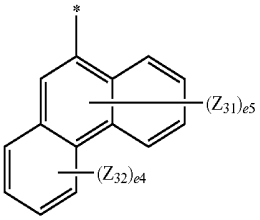


Formula 3-6

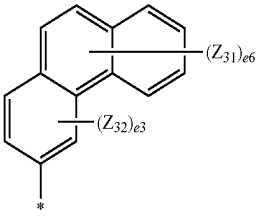


-continued

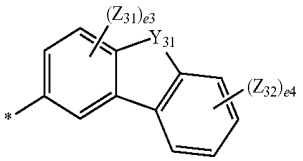
Formula 3-7



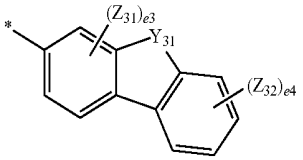
Formula 3-8



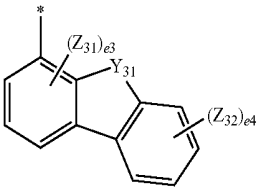
Formula 3-9



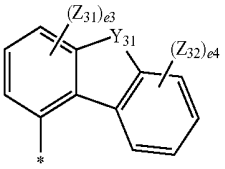
Formula 3-10



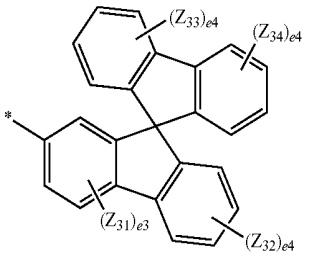
Formula 3-11



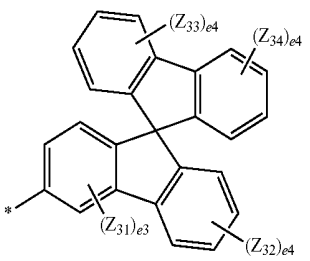
Formula 3-12



Formula 3-13



Formula 3-14



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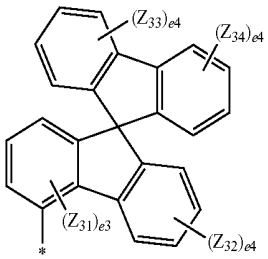
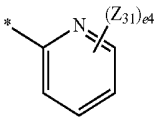
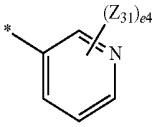
Formula 3-15



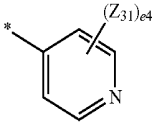
Formula 3-16



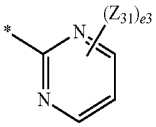
Formula 3-17



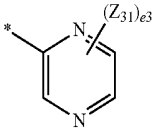
Formula 3-18



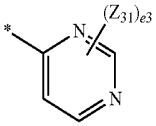
Formula 3-19



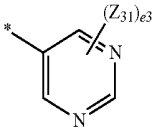
Formula 3-20



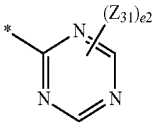
Formula 3-21



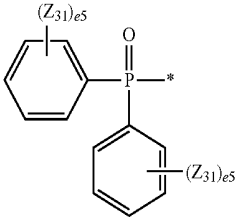
Formula 3-22



Formula 3-23



Formula 3-24



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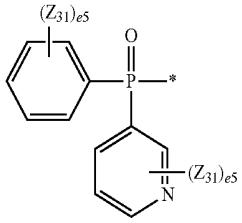
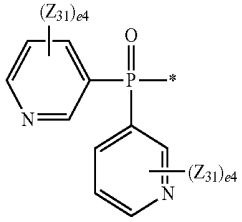
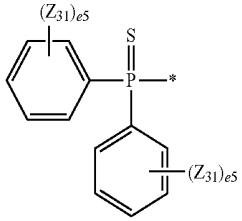
Formula 3-25



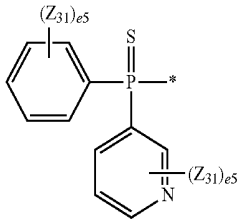
Formula 3-26



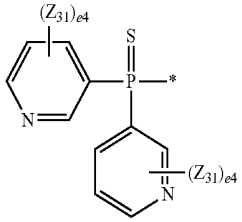
Formula 3-27



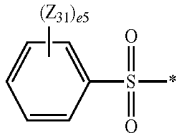
Formula 3-28



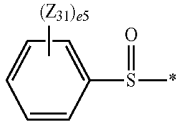
Formula 3-29



Formula 3-30



Formula 3-31



In Formulae 3-1 to 3-31:

Y_{31} may be selected from O, S, $C(Z_{35})(Z_{36})$, $N(Z_{37})$, or $Si(Z_{38})(Z_{39})$,

Z_{31} to Z_{39} may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphe-

nyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-benzofluorene-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an indolyl group, an isoindolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, an isoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphthosilolyl group, a thiadiazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafluorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indenocarbazolyl group, or an indolocarbazolyl group,

e2 may be an integer selected from 0 to 2,

e3 may be an integer selected from 0 to 3,

e4 may be an integer selected from 0 to 4,

e5 may be an integer selected from 0 to 5,

e6 may be an integer selected from 0 to 6,

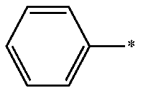
e7 may be an integer selected from 0 to 7, and

e9 may be an integer selected from 0 to 9.

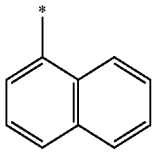
According to an exemplary embodiment of the present invention, Ar_1 to Ar_3 in Formula 1 may each independently be selected from groups represented by Formulae 3-1 to 3-4, 3-9 to 3-11, 3-13, 3-16 to 3-19, 3-23, 3-24, 3-26, 3-27, and 3-29 to 3-31.

According to an exemplary embodiment of the present invention, Ar_1 to Ar_3 in Formula 1 may each independently be selected from groups represented by Formulae 4-1 to 4-31; however, exemplary embodiments of the present invention are not limited thereto.

Formula 4-1

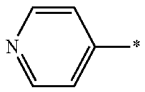


Formula 4-2

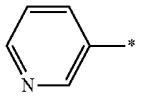


-continued

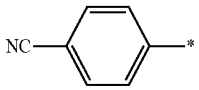
Formula 4-3



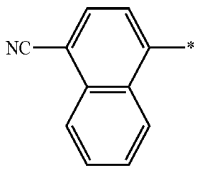
Formula 4-4



Formula 4-5



Formula 4-6



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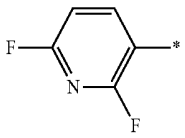

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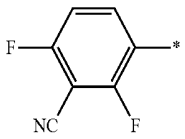

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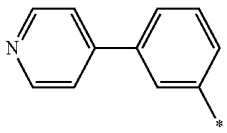

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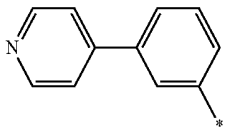

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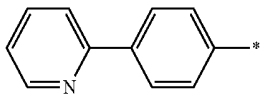

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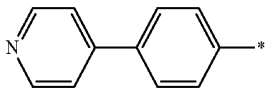

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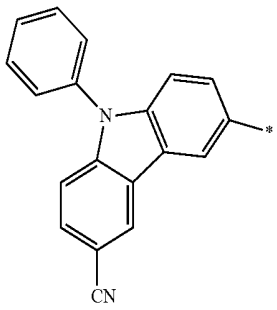

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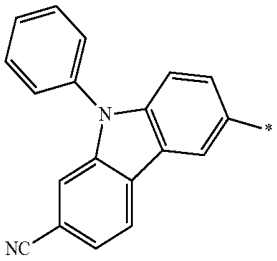

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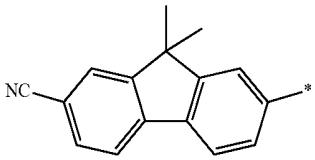

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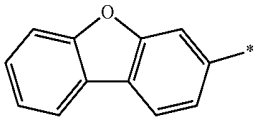

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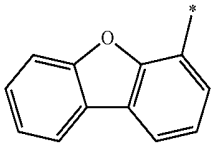

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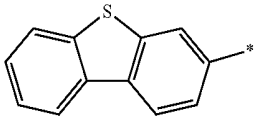

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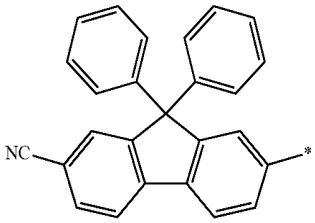

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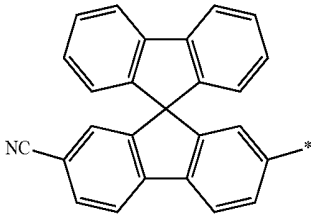

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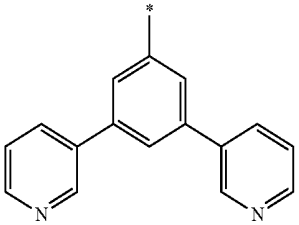

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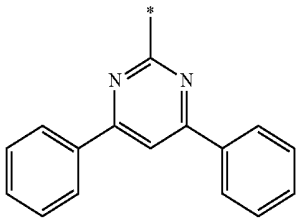

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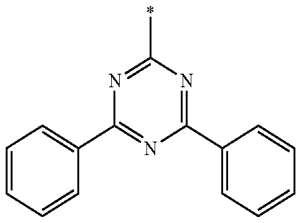

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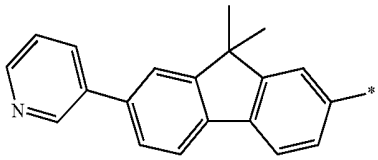

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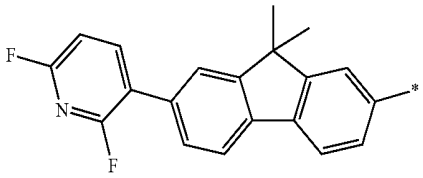

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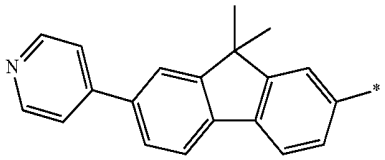

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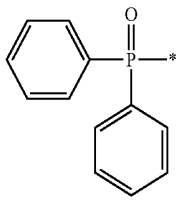

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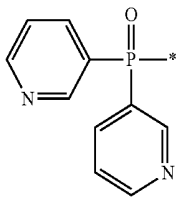

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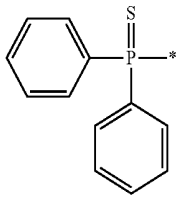

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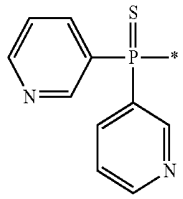

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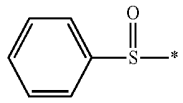


b1 to b3 in Formula 1 may each independently be an integer selected from 1 to 7; however, exemplary embodiments of the present invention are not limited thereto. When b1 is 2 or greater, at least two Ar_1(s) may be the same or different from each other. When b2 is 2 or greater, at least two Ar_2(s) may be the same or different from each other. When b3 is 2 or greater, at least two Ar_3(s) may be the same or different from each other.

According to an exemplary embodiment of the present invention, b1 to b3 in Formula 1 may each independently be an integer selected from 1 to 3; however, exemplary embodiments of the present invention are not limited thereto. For example, in Formula 1, b1 may be 0, b2 may be 0, and b3 may be 1 or 2; however, exemplary embodiments of the present invention are not limited thereto.

According to an exemplary embodiment of the present invention, c1 and c3 in Formula 1 may each independently be an integer selected from 0 to 6, and c2 may be an integer selected from 0 to 2. However, exemplary embodiments of the present invention are not limited thereto.

According to an exemplary embodiment of the present invention, c1 to c3 may satisfy the formula of c1+c2+c3≥1.

According to an exemplary embodiment of the present invention, c1 to c3 in Formula 1 may satisfy the formula of c1+c2+c3=1. For example, in Formula 1, c1 may be 0, c2 may be 0, and c3 may be 1; however, exemplary embodiments of the present invention are not limited thereto.

R_{11}, R_{12}, and R_{13} in Formula 1 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_{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, —$Si(Q_1)(Q_2)(Q_3)$, or —$S(=O)_2(Q_1)$; however, exemplary embodiments of the present invention are not limited thereto.

According to an exemplary embodiment of the present invention, R_{11} to R_{13} in Formula 1 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, or a C_1-C_{20} alkoxy group;

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, a nitro group, an amidino group, a hydrazino group, or a hydrazono group;

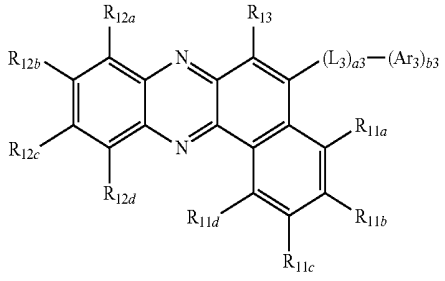
a cyclopentyl group, a cyclohexyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, or a terphenyl group; or

a cyclopentyl group, a cyclohexyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl 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 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 cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, or a terphenyl group. However, exemplary embodiments of the present invention are not limited thereto.

In Formula 1, a11 and a12 may each independently be an integer selected from 0 to 6. a13 may be an integer selected from 0 to 2. However, exemplary embodiments of the present invention are not limited thereto. When a11 is 2 or greater, at least two R_{11}(s) may be the same or different from each other. When a12 is 2 or greater, at least two R_{12}(s) may be the same or different from each other. When a13 is 2, two of R_{13}(s) may be the same or different from each other. For example, a11 to a13 may each independently be an integer selected from 0 to 2; however, exemplary embodiments of the present invention are not limited thereto.

In one or more exemplary embodiments of the present invention, the compound represented by Formula 1 may be represented by Formula 1-1; however, exemplary embodiments of the present invention are not limited thereto.

<Formula 1-1>



L_3, a3, Ar_3, b3, and R_{13} in Formula 1-1 may be the same as described above.

R_{11a} to R_{11d} and R_{12a} to R_{12d} in Formula 1-1 may be the same as described above with respect to R_{11} and R_{12}.

The condensed cyclic compound represented by Formula 1 may be one selected from Compounds 1 to 60; however, exemplary embodiment of the present invention are not limited thereto.

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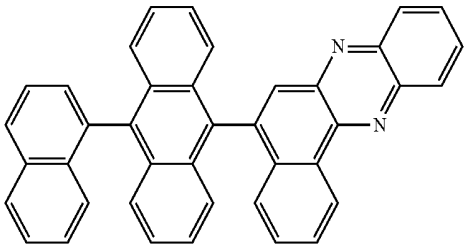
1



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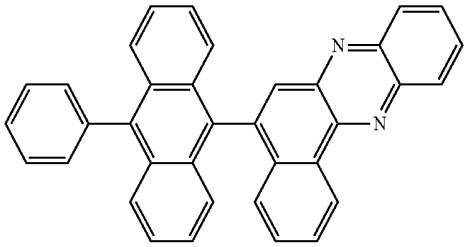

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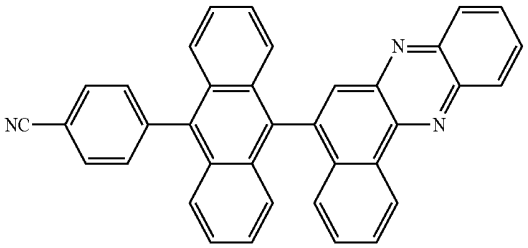

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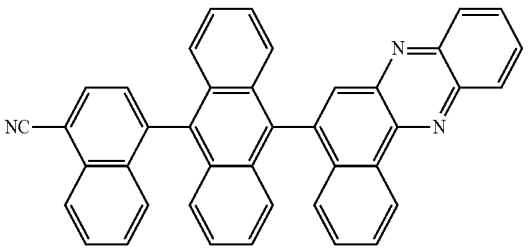

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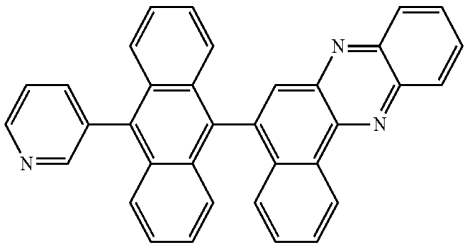

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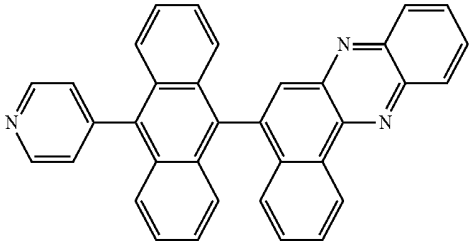

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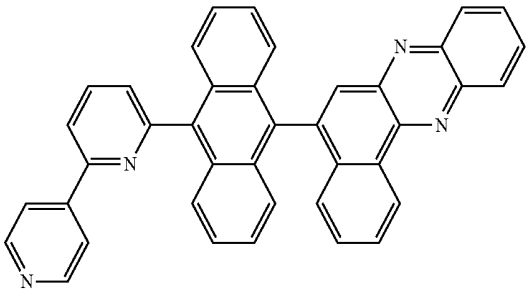

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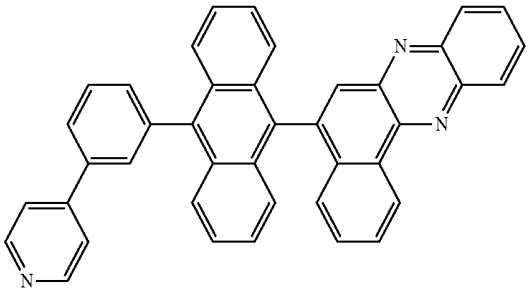

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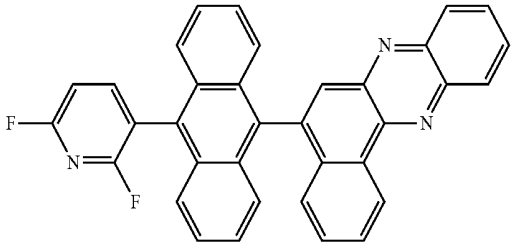

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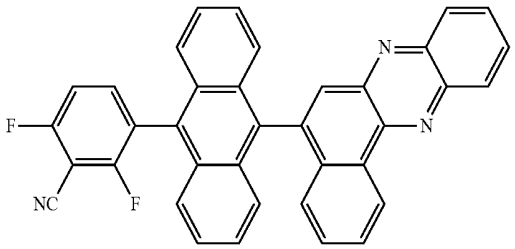

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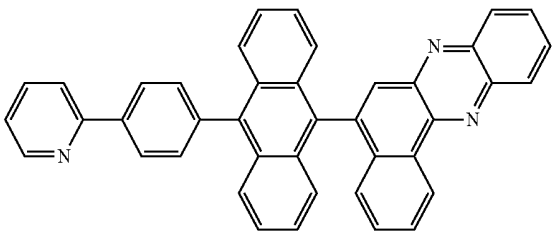

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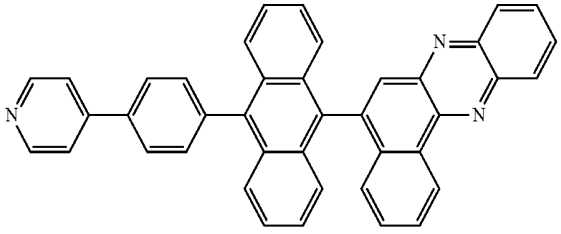

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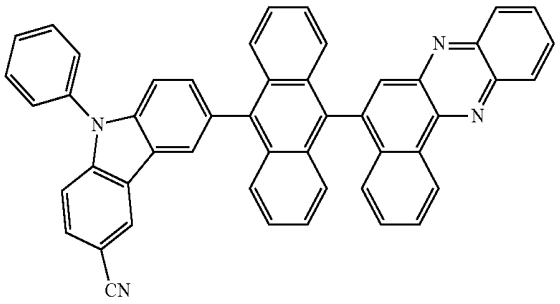

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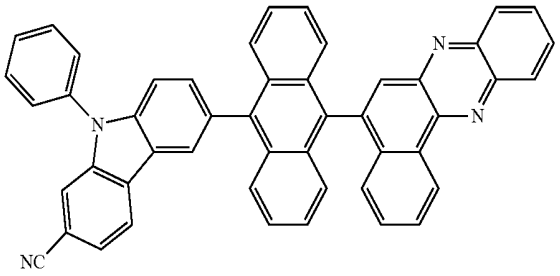

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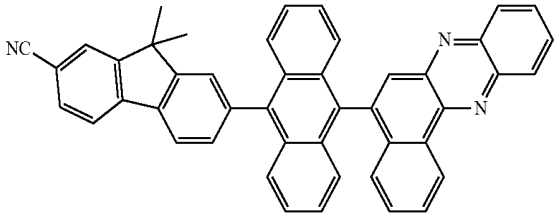

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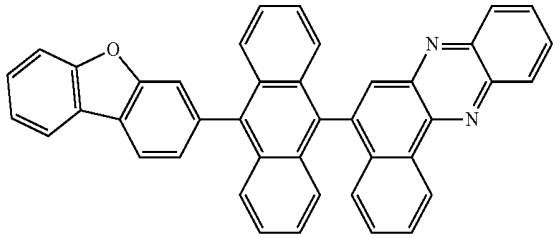

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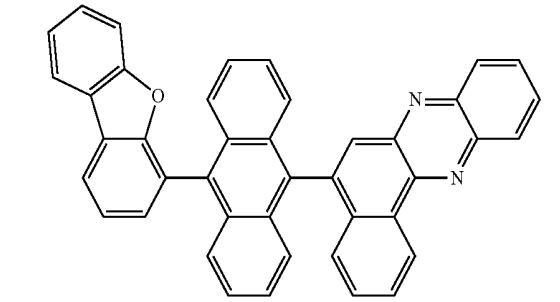

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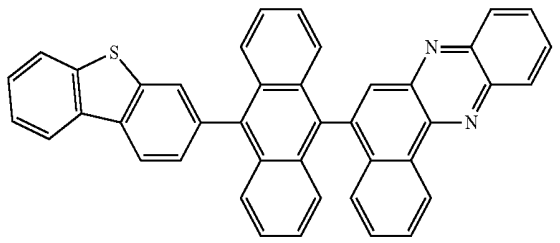

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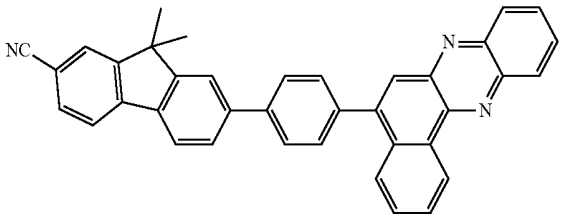

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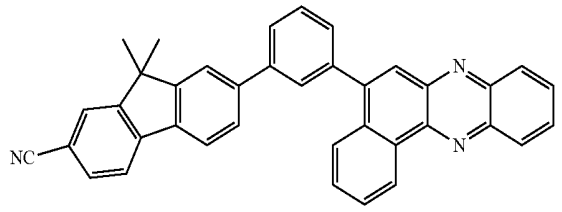

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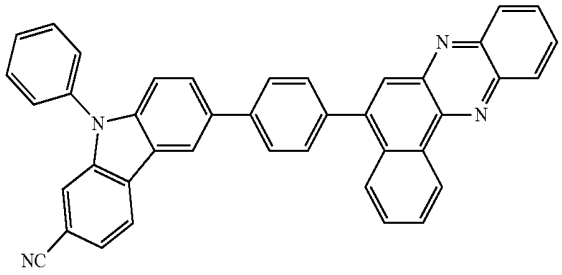

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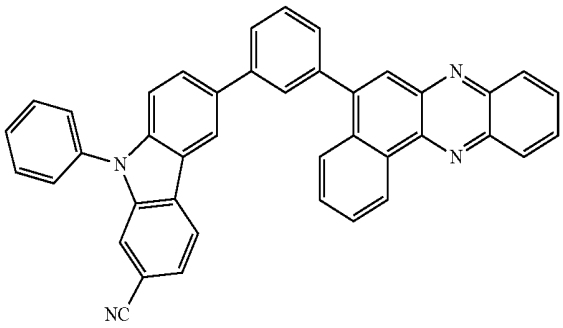

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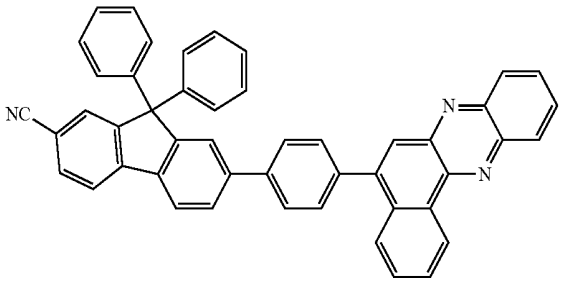

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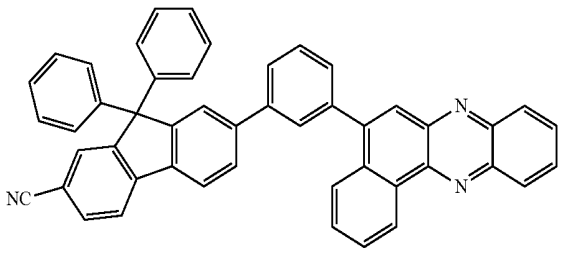

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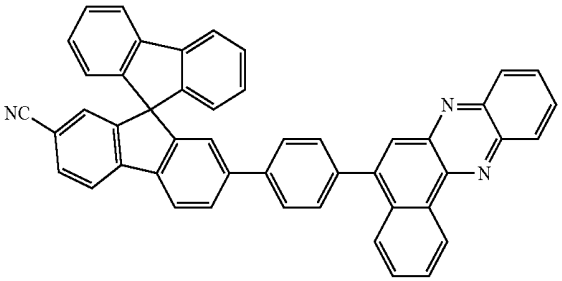

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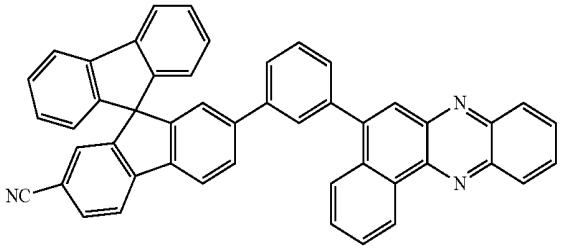

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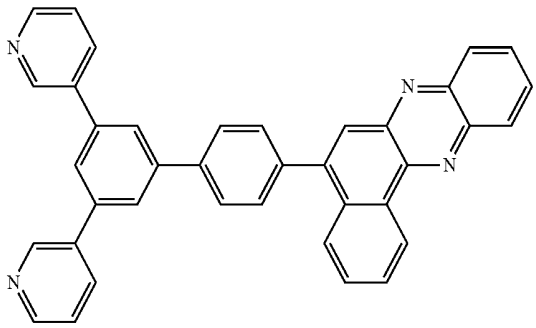

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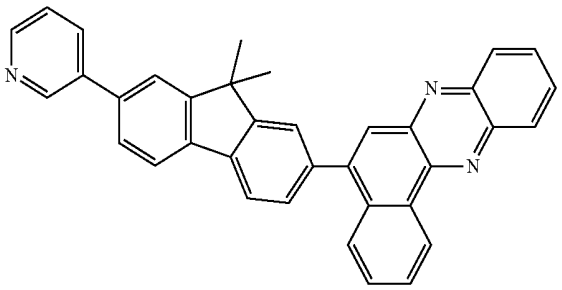

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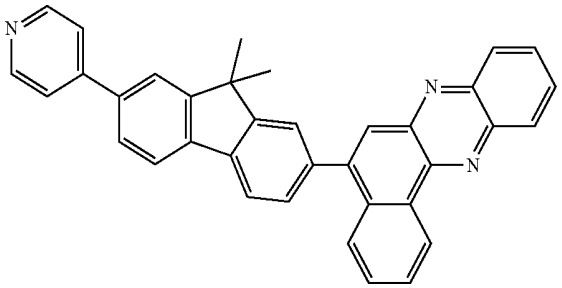

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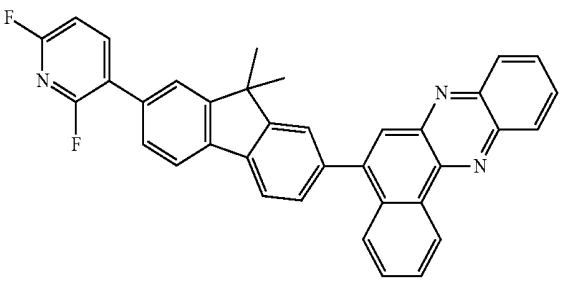

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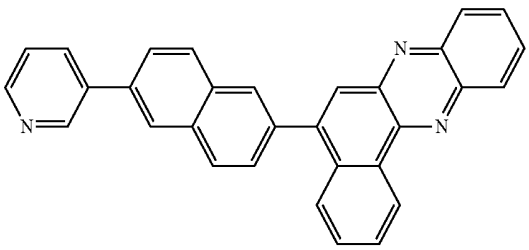

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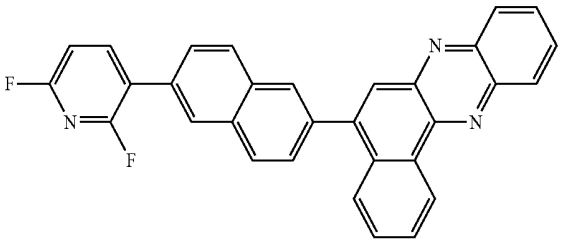

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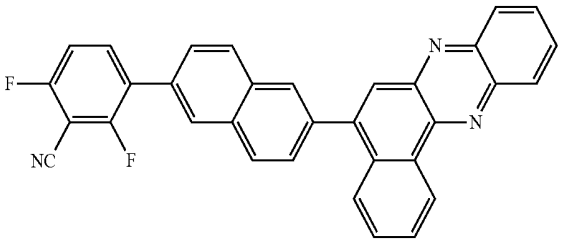

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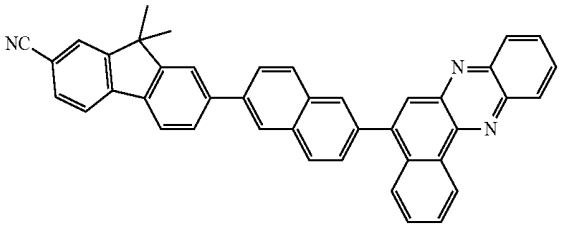

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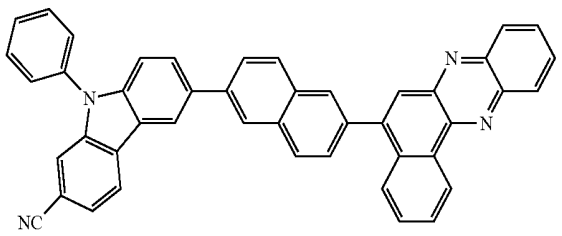

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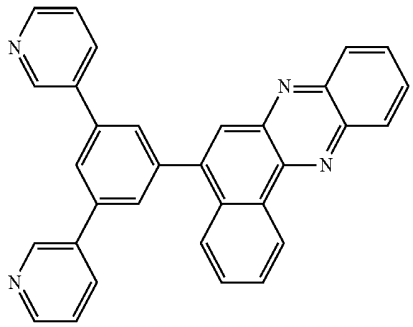

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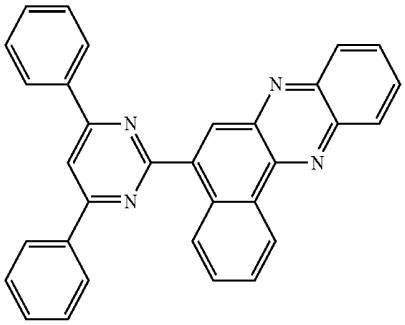

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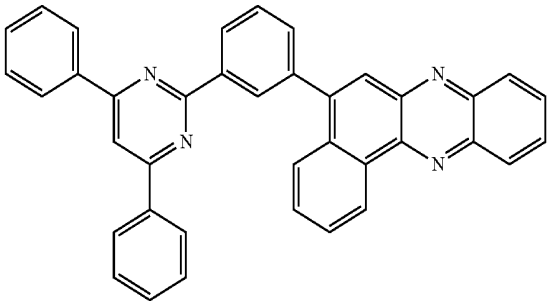

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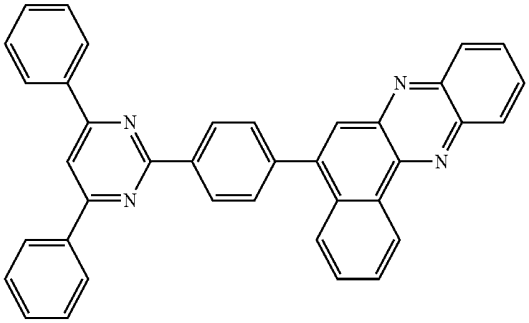

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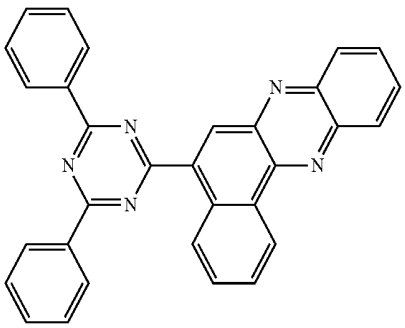

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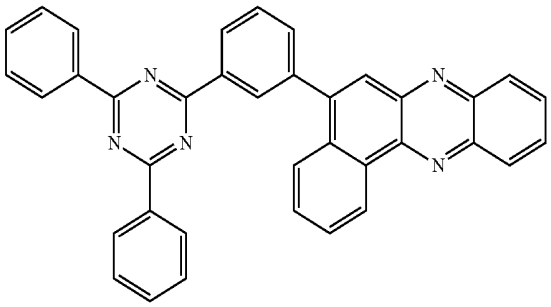

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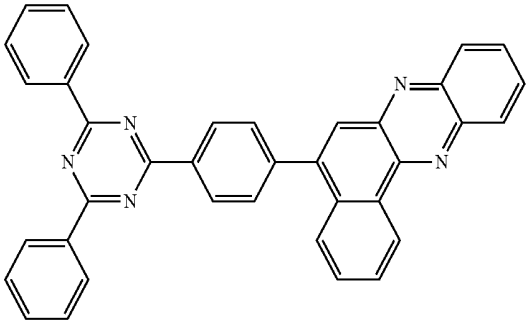

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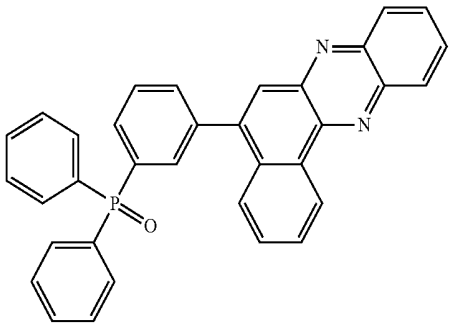

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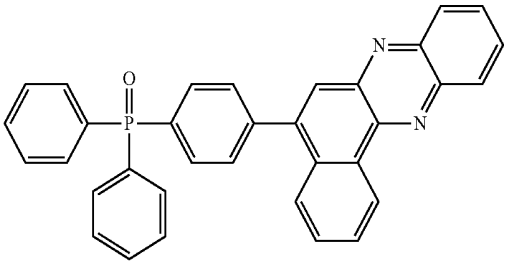

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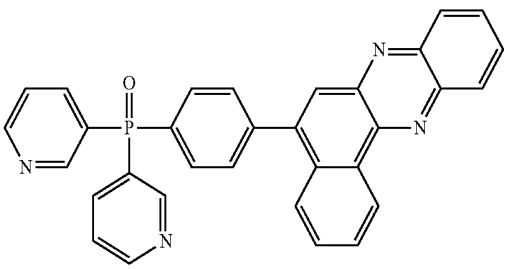

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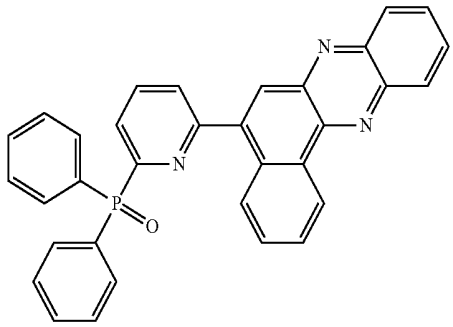

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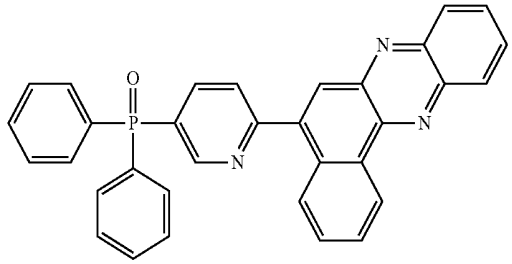

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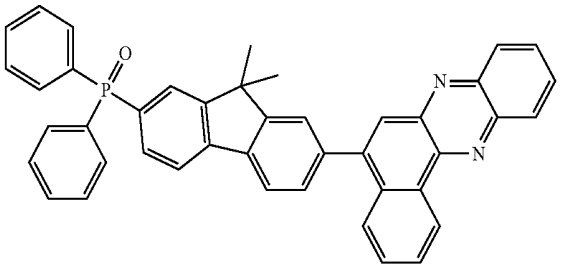

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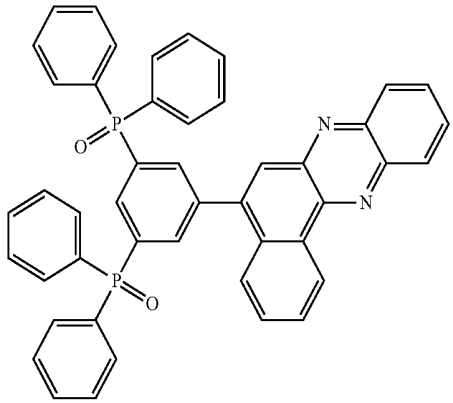

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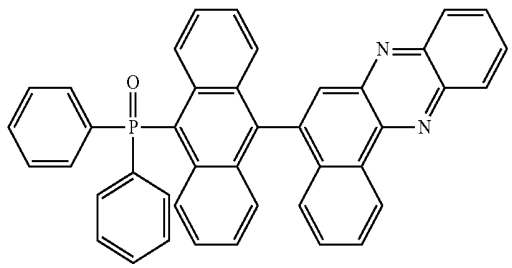

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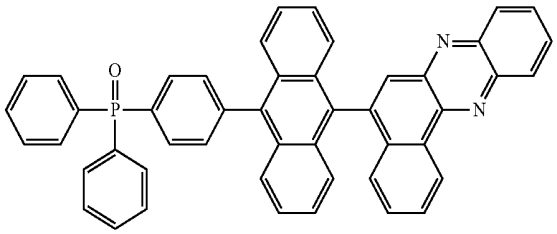

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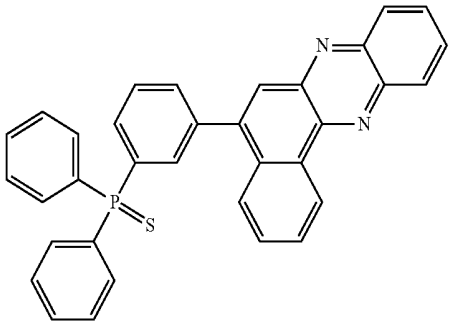

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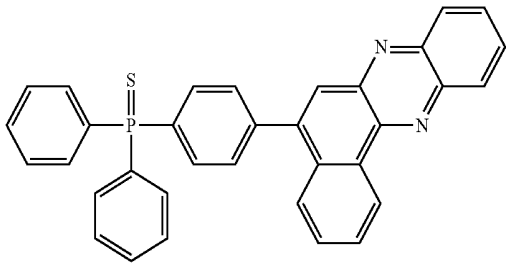

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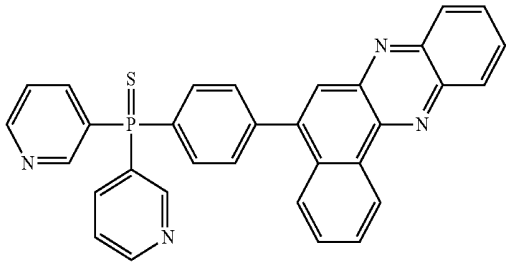

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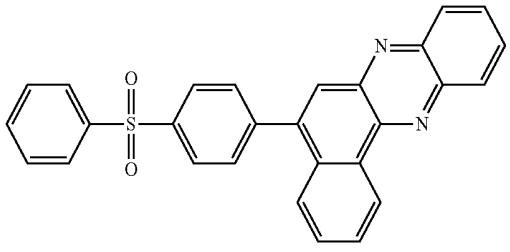

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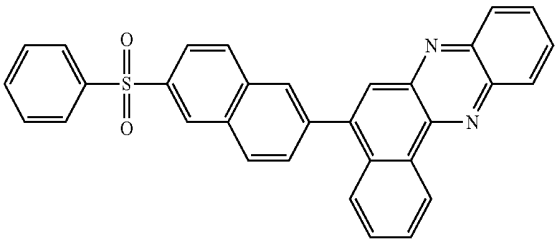

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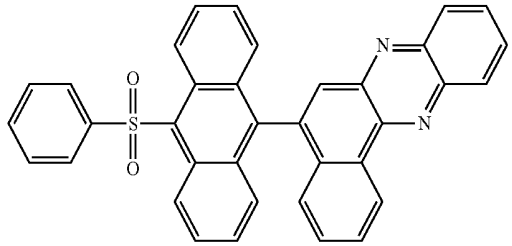

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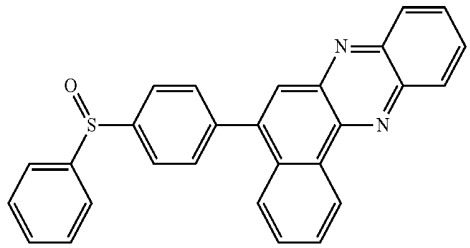

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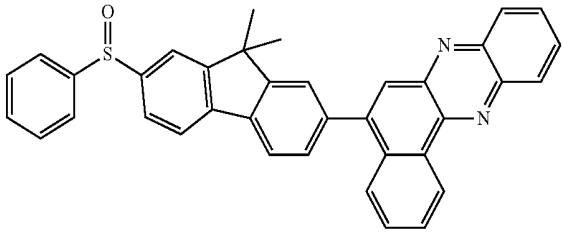

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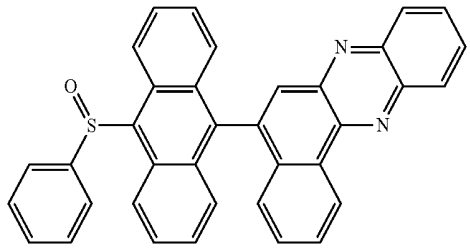


Since the condensed cyclic compound represented by Formula 1 may include a phenazine condensed with a benzene group on both sides of a quinoxaline group, the condensed cyclic compound may have an increased heat resistance and an increased electron transport capability due to a planar core structure. Thus, an electronic device (e.g., an organic light-emitting device) which includes the condensed cyclic compound represented by Formula 1 may have relatively high efficiency, a relatively high driving voltage, relatively high luminance, and a relatively long lifespan.

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

At least one of the condensed cyclic compounds represented by Formula 1 may be used between a pair of electrodes of an organic light-emitting device. According to an exemplary embodiment of the present invention, the condensed cyclic compound may be included in at least one of an electron transport region and an emission layer. For example, the condensed cyclic compound may be included in the electron transport region.

One or more exemplary embodiments of the present invention provide an organic light-emitting device. The organic light-emitting device may include a first electrode, a second electrode, and an organic layer. The second electrode may face the first electrode. The organic layer may be disposed between the first electrode and the second electrode. The organic layer may include an emission layer. The organic layer may include at least one of the condensed cyclic compounds represented by Formula 1.

The expression "(an organic layer) includes at least one of the condensed cyclic compounds" as 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 Formula 1."

For example, the organic layer may include, as the condensed cyclic compound, only Compound 1. In this regard, Compound 1 may be in an electron transport layer of the organic light-emitting device. According to an exemplary embodiment of the present invention, the organic layer may include, as the condensed cyclic compound, Compound 1 and Compound 2. According to an exemplary embodiment of the present invention, Compound 1 and Compound 2 may both be in an identical layer. For example, Compound 1 and Compound 2 may both be in an electron transport layer. Alternatively, Compound 1 and Compound 2 may be in different layers. For example, Compound 1 may be in an electron transport layer and Compound 2 may be in an electron injection layer.

According to an exemplary embodiment of the present invention, the first electrode of the organic light-emitting device may be an anode. The second electrode of the organic light-emitting device may be a cathode. The organic layer may include a hole transport region and an electron transport region. The hole transport region may be disposed between the first electrode and the emission layer. The hole transport region may include at least one of a hole injection layer, a hole transport layer, a buffer layer, and an electron-blocking layer. The electron transport region may be disposed between the emission layer and the second electrode. The electron transport region may include at least one of a hole blocking layer, an electron transport layer, or an electron injection layer. For example, the electron transport region may include a single layer or a plurality of layers.

According to an exemplary embodiment of the present invention, the electron transport region may include the electron transport layer. The electron transport layer may include at least one of the condensed cyclic compounds. According to an exemplary embodiment of the present invention, the emission layer of the organic light-emitting device may include a fluorescent compound. However, exemplary embodiments of the present invention are not limited thereto. According to an exemplary embodiment of the present invention, the emission layer may include an arylamine-based compound or a styryl-based compound.

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.

FIG. **1** is a schematic cross-sectional diagram illustrating an organic light-emitting device according to an exemplary embodiment of the present invention. An organic light-emitting device **10** may include a first electrode **110**, an organic layer **150**, and a second electrode **190**.

A structure of the organic light-emitting device **10** according to an exemplary embodiment of the present invention and a method of manufacturing the organic light-emitting

device **10** according to an exemplary embodiment of the present invention will be described in more detail with reference to FIG. **1**.

Referring to FIG. **1**, a substrate may be 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 have a relatively high mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and water-resistance.

The first electrode **110** may be formed by depositing or sputtering a material for forming the first electrode **110** on the substrate. When the first electrode **110** is an anode, the material for forming the first electrode **110** may include materials with a high work function which may facilitate hole injection.

The first electrode **110** may be a reflective electrode, a semi-transmissive electrode, or a transmissive electrode. When the first electrode **110** is a transmissive electrode, a material for forming the first electrode **110** may include indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO_2), zinc oxide (ZnO), or any combinations thereof; however, exemplary embodiments of the present invention are not limited thereto. When the first electrode **110** is a semi-transmissive electrode or a reflective electrode, a material for forming 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), or any combination thereof. However, the material for forming the first electrode **110** is not limited thereto.

The first electrode **110** may have a single-layered structure. Alternatively, the first electrode **110** may have a multi-layered structure include two or more layers. For example, the first electrode **110** may have a three-layered structure of ITO/Ag/ITO; however, the structure of the first electrode **110** is not limited thereto.

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

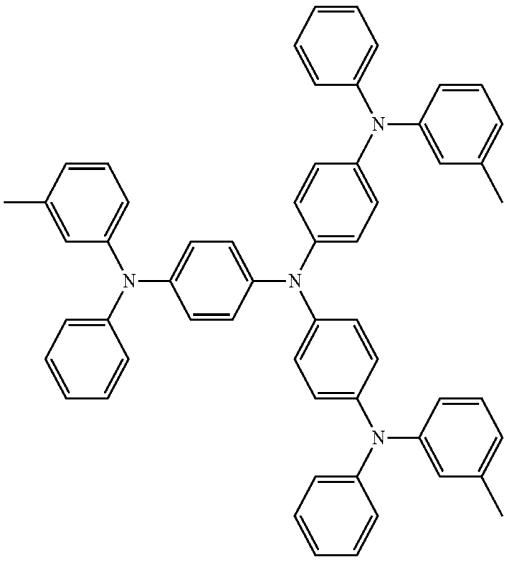
The organic layer **150** may include a hole transport region and an electron transport region. The hole transport region may be disposed between the first electrode **110** and the emission layer. The electron transport region may be disposed between the emission layer and the second electrode **190**.

The hole transport region may have a single-layered structure including a single layer including a single material. The hole transport layer may have a single-layered structure including a single layer including a plurality of different materials. The hole transport layer may have a multi-layered structure having a plurality of layers, each including a plurality of different materials.

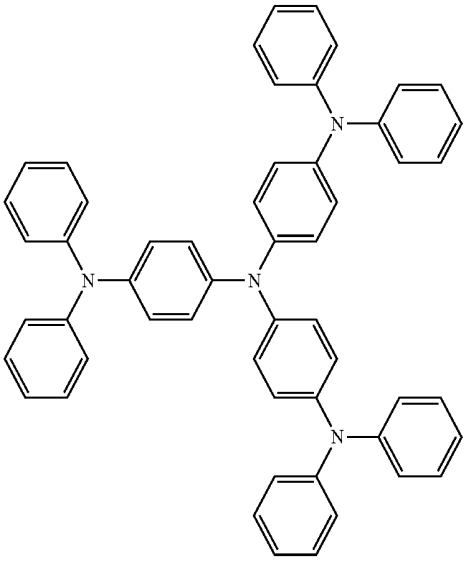
The hole transport region may include at least one layer selected from a hole injection layer, a hole transport layer, an emission auxiliary layer, or an electron-blocking layer.

For example, the hole transport region may have a single-layered structure. 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. The multi-layered structure may include a hole injection layer/hole transport layer structure, a hole injection layer/hole transport layer/emission auxiliary layer structure, a hole injection layer/emission auxiliary layer structure, a hole transport layer/emission auxiliary layer structure, or a hole injection layer/hole transport layer/electron-blocking layer structure. For each structure, the layers may be sequentially stacked on the first electrode **110**; however, the structure of the hole transport region is not limited thereto.

The hole transport region may include at least one of 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), PEDOT/PSS (poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate)), polyaniline/camphor sulfonic acid (Pani/CSA), polyaniline/poly(4-styrenesulfonate) (Pani/PSS), a compound represented by Formula 201, or a compound represented by Formula 202:



m-MTDATA



TDATA

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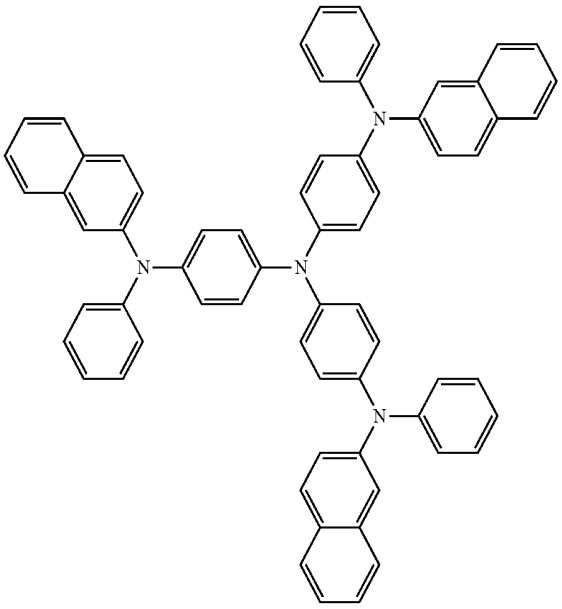

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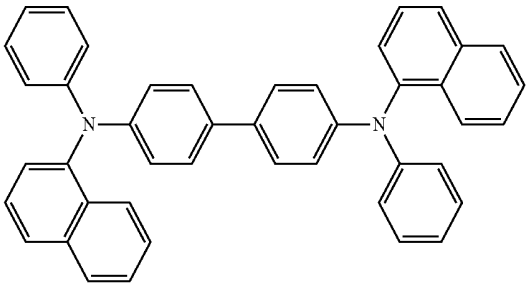
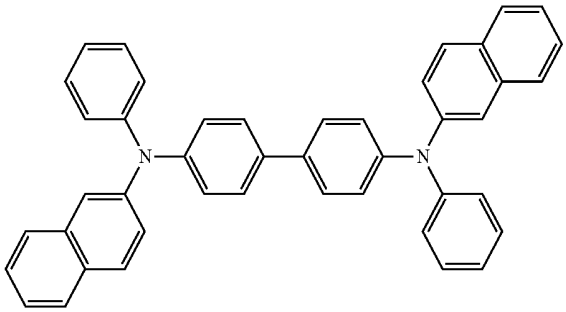
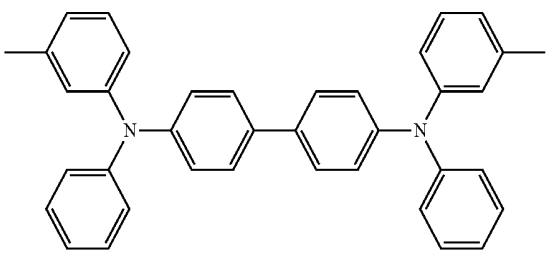


NPB



β-NPB



TPD

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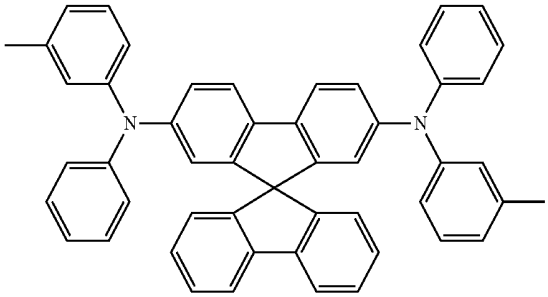
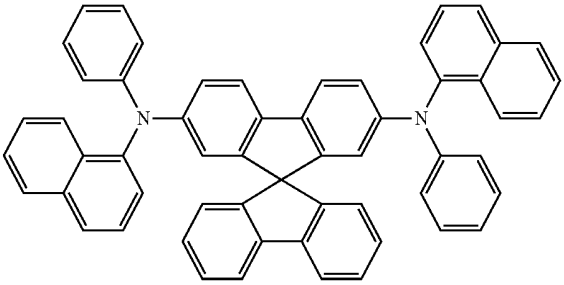
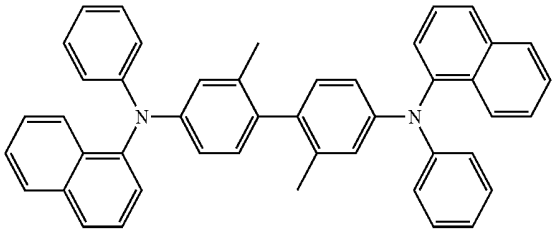


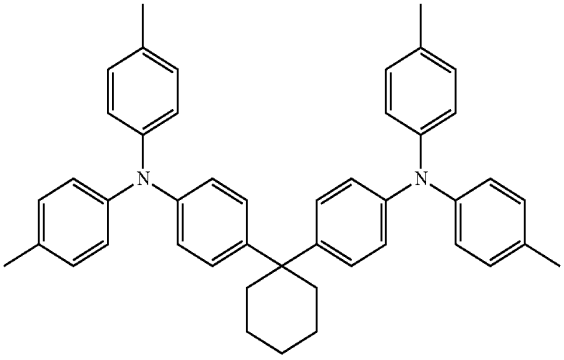
Spiro-TPD



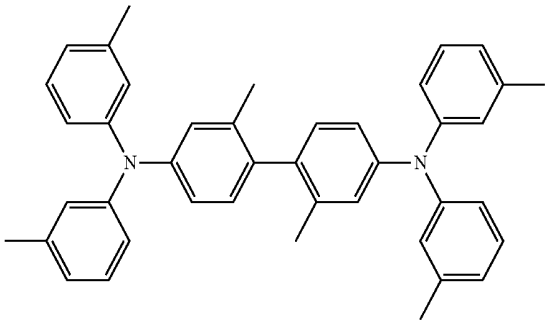
Spiro-NPB



methylated NPB



TAPC



HMTPD

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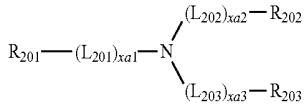
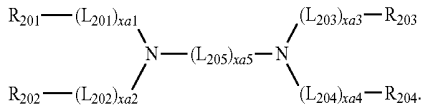
<Formula 201>



<Formula 202>



In Formulae 201 and 202:

L_{201} to L_{204} may each independently be selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3-C_{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, or a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

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

xa1 to xa4 may each independently be an integer selected from 0 to 3.

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

R_{201} to R_{204} and Q_{201} may each independently be selected from a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{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, or a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group.

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

According to an exemplary embodiment of the present invention, in Formulae 201 and 202, L_{201} to L_{205} may each independently be selected from:

a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an 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 fluoranthenylene 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, or a pyridinylene group; or

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 fluoranthenylene 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 C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1-C_{10} alkyl group, a phenyl group substituted with —F, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, —Si(Q_{31})(Q_{32})(Q_{33}), or —N(Q_{31})(Q_{32}).

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, or a naphthyl group.

According to an exemplary embodiment of the present invention, in Formulae 201 and 202, xa1 to xa4 may each independently be an integer selected from 0, 1, or 2.

According to an exemplary embodiment of the present invention, in Formulae 201 and 202, xa5 may be an integer selected from 1, 2, 3, or 4.

According to an exemplary embodiment of the present invention, in Formulae 201 and 202, R_{201} to R_{204} and Q_{201} may each independently be selected from: a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an

indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, or a pyridinyl group; or

a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1-C_{10} alkyl group, a phenyl group substituted with —F, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, —Si(Q_{31})(Q_{32})(Q_{33}), or —N(Q_{31})(Q_{32}).

Q_{31} to Q_{33} may be the same as described above.

According to an exemplary embodiment of the present invention, at least one of R_{201} to R_{203} in Formula 201 may each independently be selected from:

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

a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1-C_{10} alkyl group, a phenyl group substituted with —F, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, or a dibenzothiophenyl group; however, exemplary embodiments of the present invention are not limited thereto.

According to an exemplary embodiment of the present invention, in Formula 202, R_{201} and R_{202} may be linked via a single bond and/or R_{203} and R_{204} may be linked via a single bond.

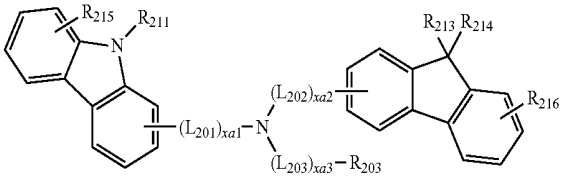
According to an exemplary embodiment of the present invention, at least one of R_{201} to R_{204} in Formula 202 may be selected from:

a carbazolyl group; or

a carbazolyl group, substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1-C_{10} alkyl group, a phenyl group substituted with —F, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, or a dibenzothiophenyl group; however, exemplary embodiments of the present invention are not limited thereto.

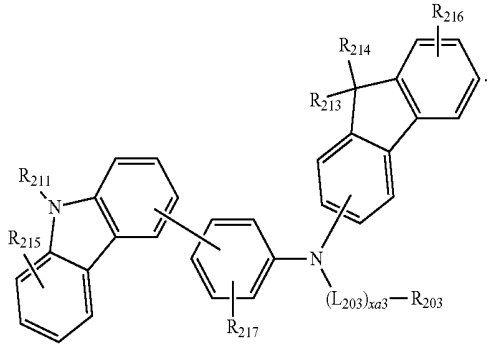
The compound represented by Formula 201 may be represented by Formula 201A:

<Formula 201A>



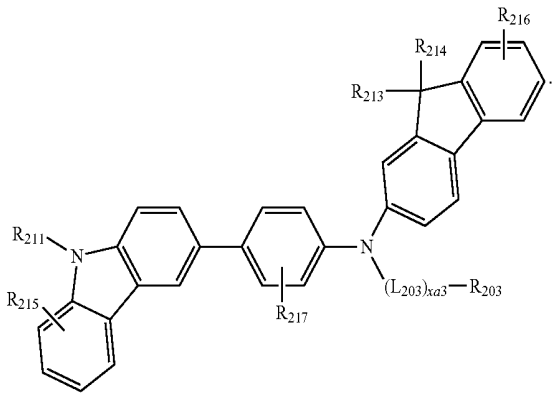
The compound represented by Formula 201 may be represented by Formula 201A(1); however, exemplary embodiments of the present invention are not limited thereto:

<Formula 201A1)>



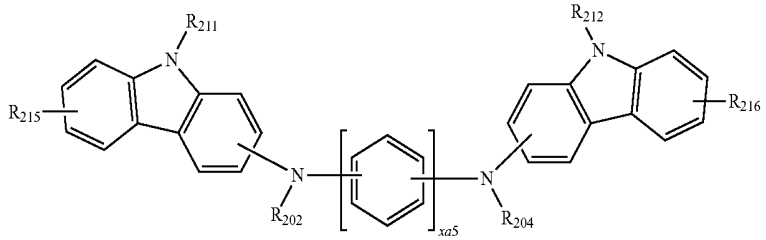
The compound represented by Formula 201 may be represented by Formula 201A-1; however, exemplary embodiments of the present invention are not limited thereto:

<Formula 201A-1>



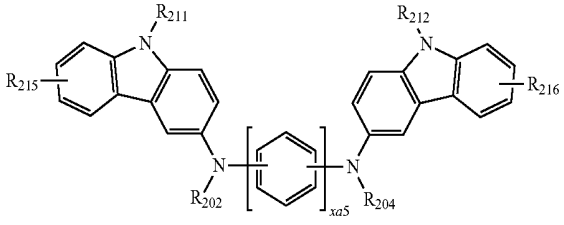
According to an exemplary embodiment of the present invention, the compound represented by Formula 202 may be represented by Formula 202A:

<Formula 202A>



According to an exemplary embodiment of the present invention, the compound represented by Formula 202 may be represented by Formula 202A-1:

<Formula 202A-1>



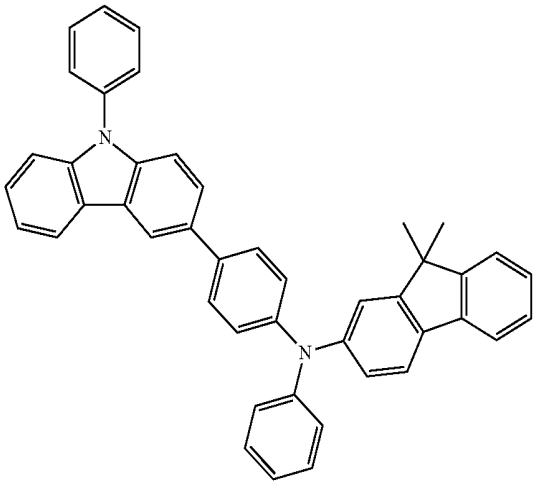
In Formulae 201A, 201A(1), 201A-1, 202A, and 202A-1, L_{201} to L_{203}, xa1 to xa3, xa5, and R_{202} to R_{204} may be the same as described above.

In Formulae 201A, 201A(1), 201A-1, 202A, and 202A-1, R_{211} and R_{212} may be understood by referring to the description provided herein with reference to R_{203}.

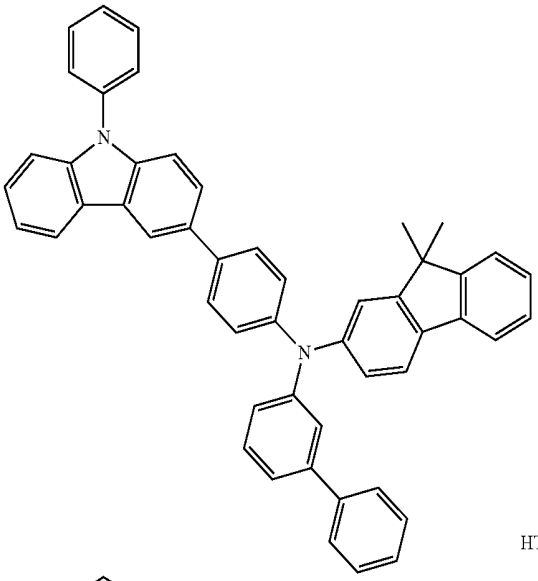
In Formulae 201A, 201A(1), 201A-1, 202A, and 202A-1, R_{213} to R_{217} may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1-C_{10} alkyl group, a phenyl group substituted with —F, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, or a pyridinyl group.

The hole transport region may include at least one compound selected from Compounds HT1 to HT39; however, exemplary embodiments of the present disclosure are not limited thereto:

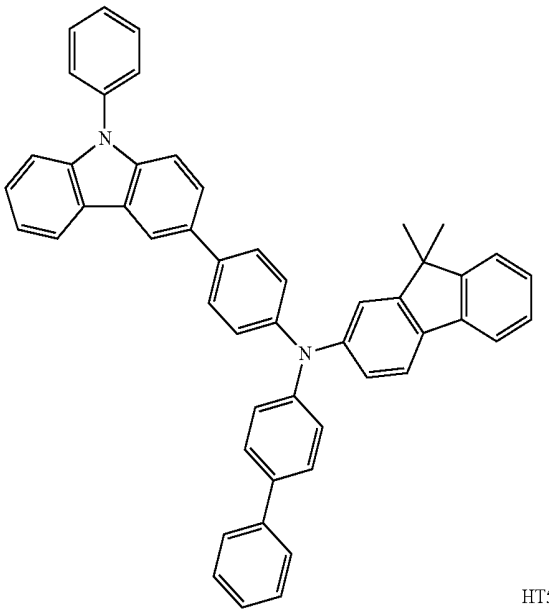
HT1



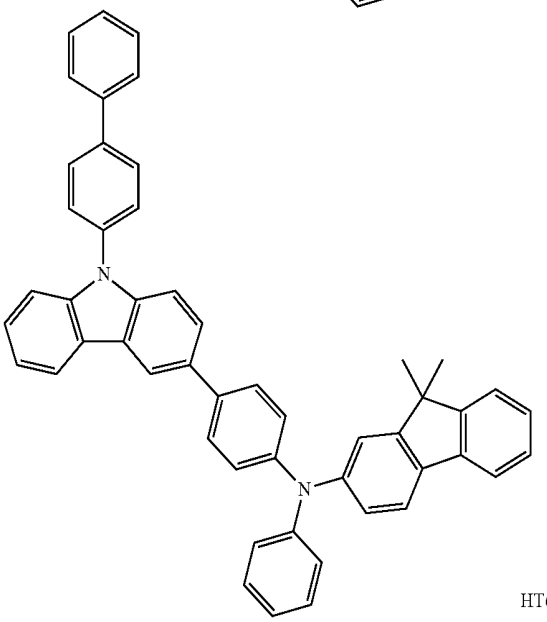
HT2



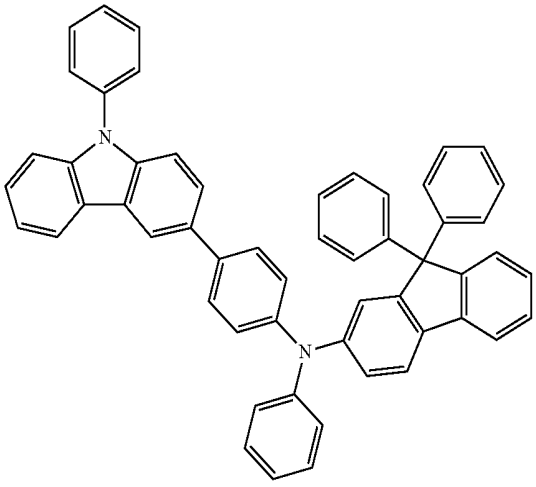
HT3



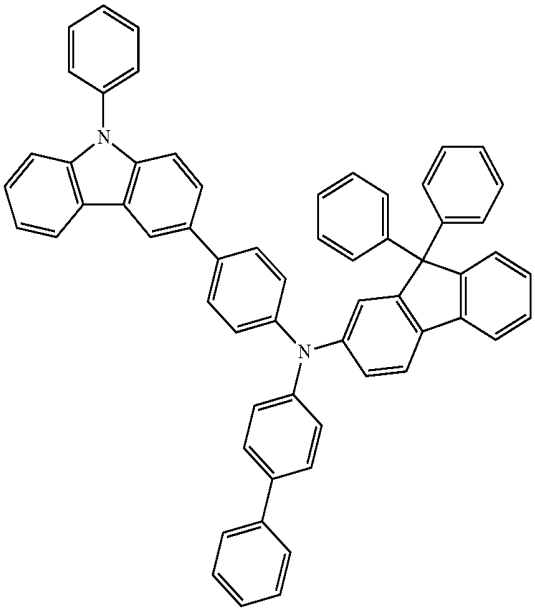
HT4



HT5



HT6



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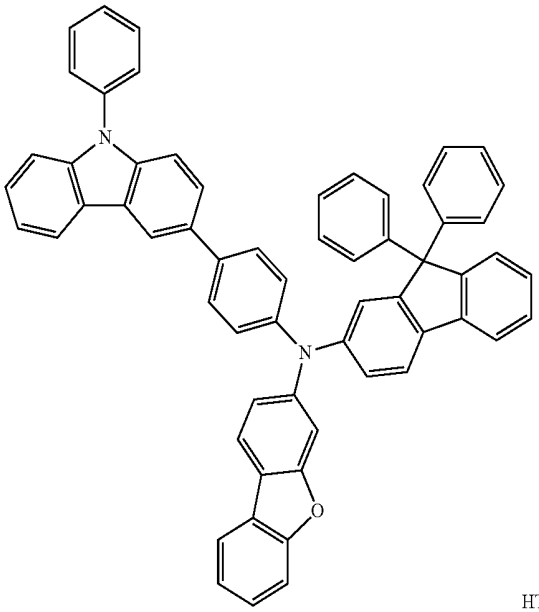
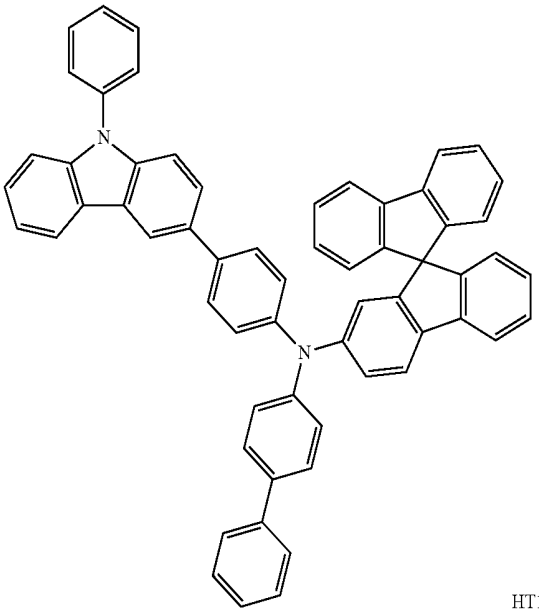
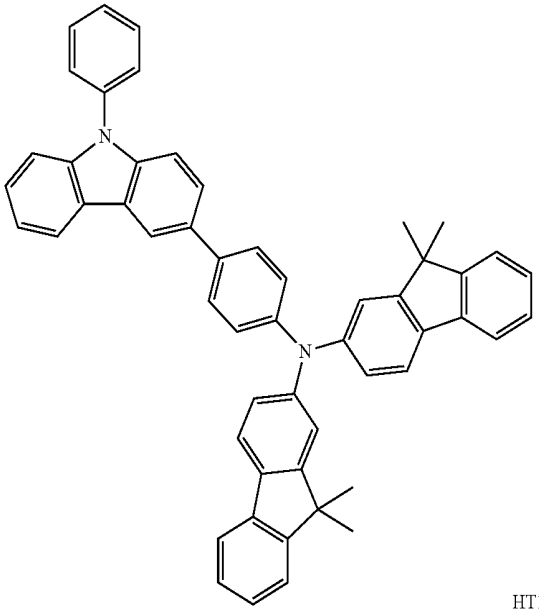
HT7



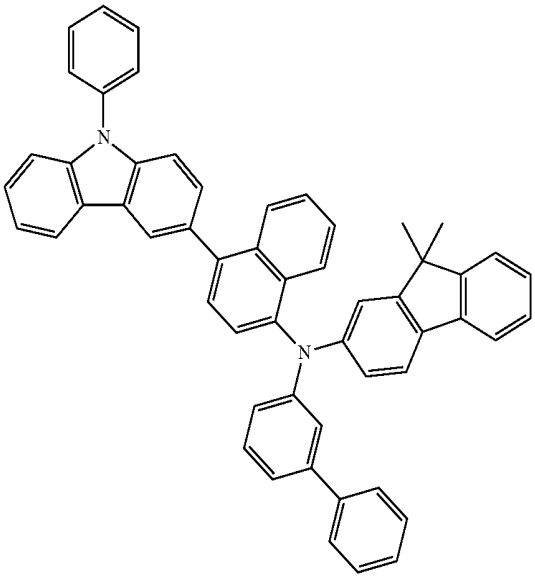
HT8



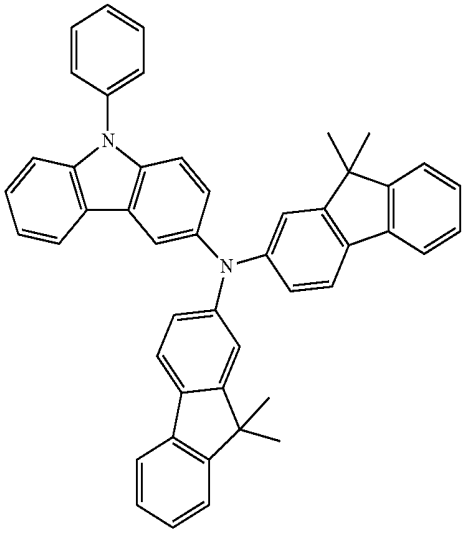
HT9



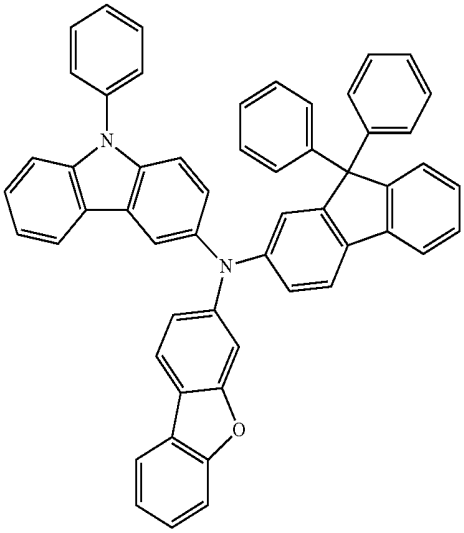
HT10



HT11



HT12



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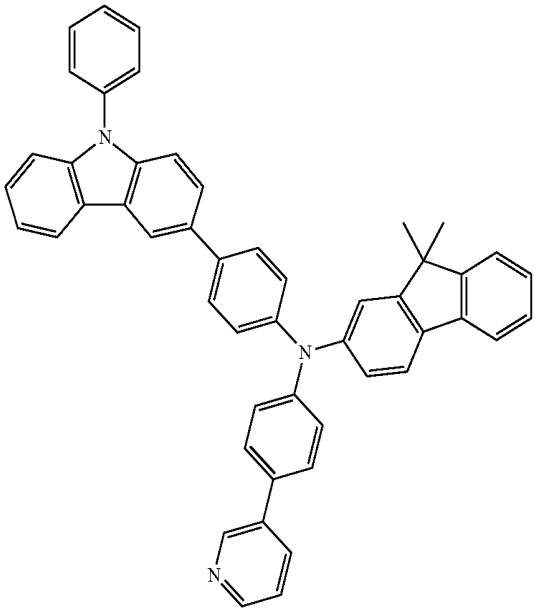
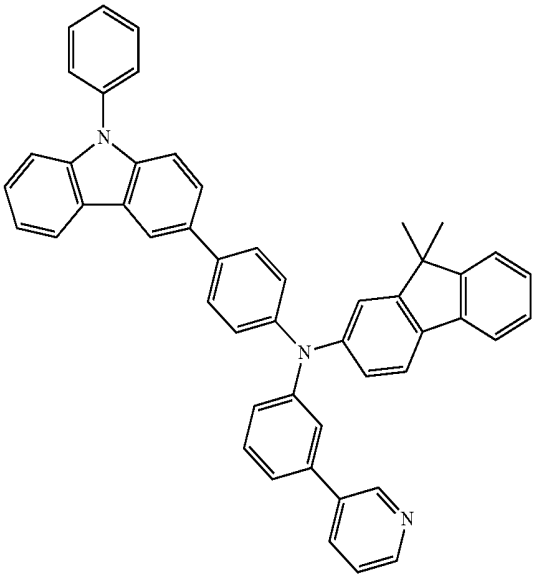
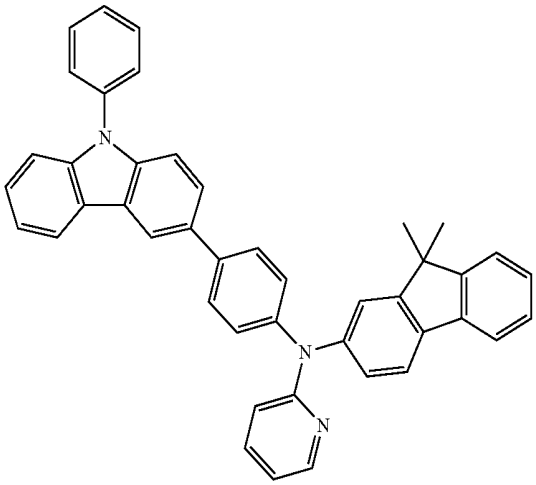
HT13



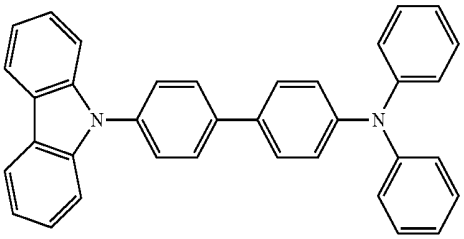
HT14



HT15



HT16



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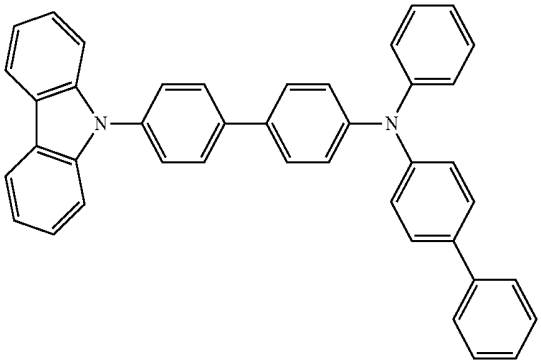

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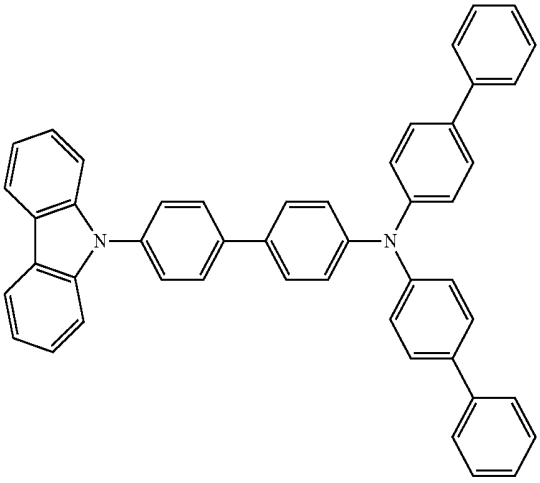

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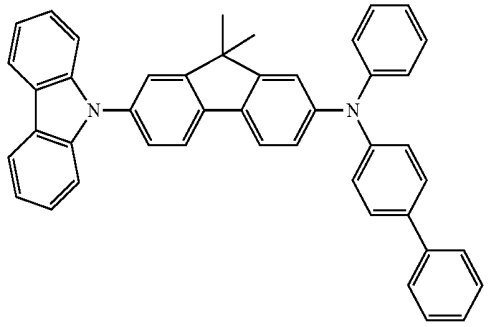

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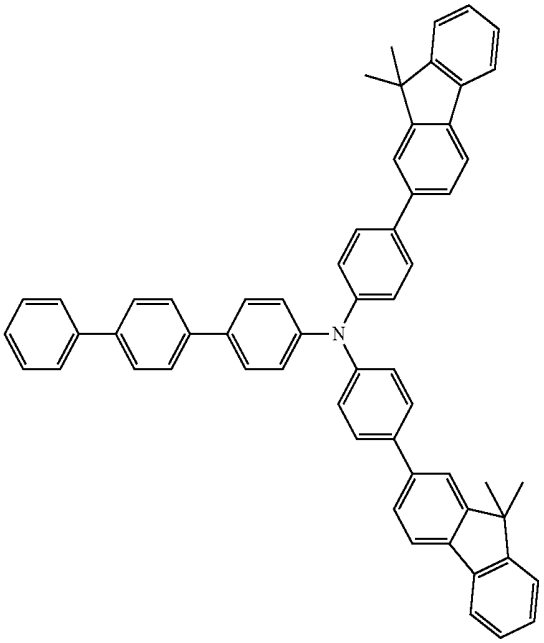

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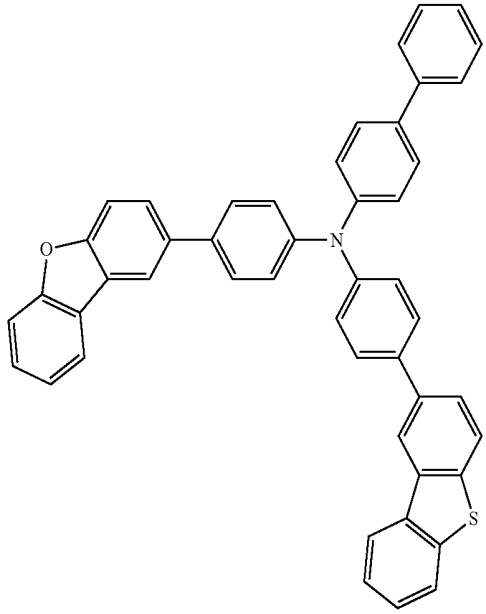

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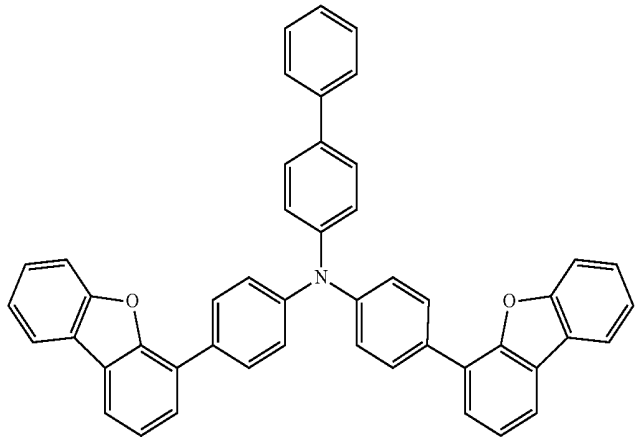

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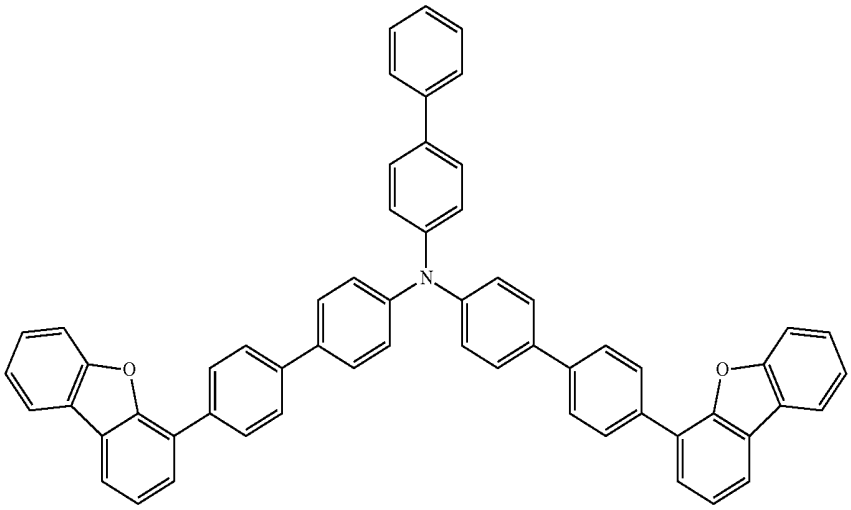

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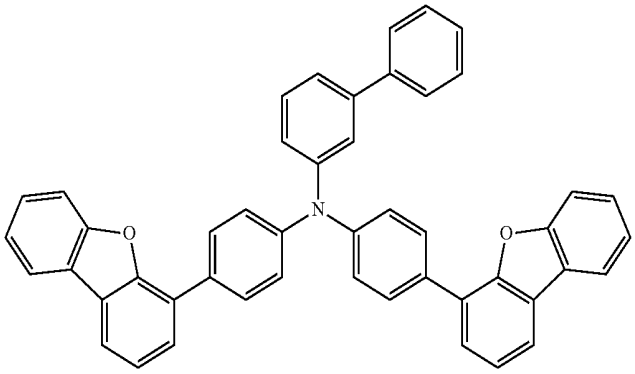

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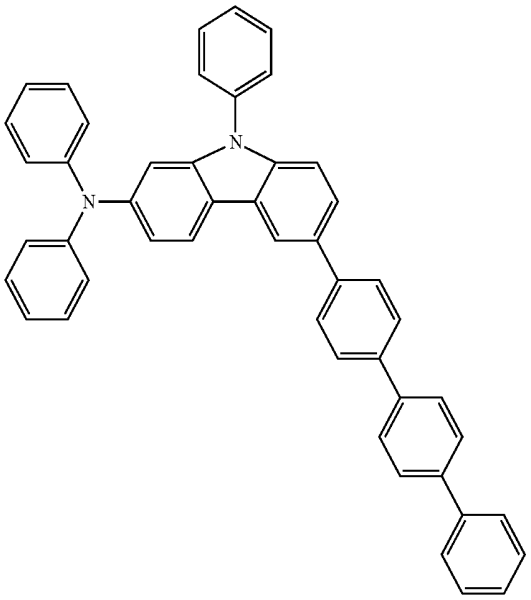

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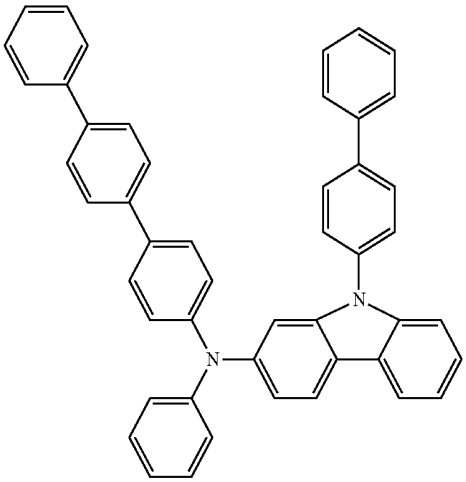

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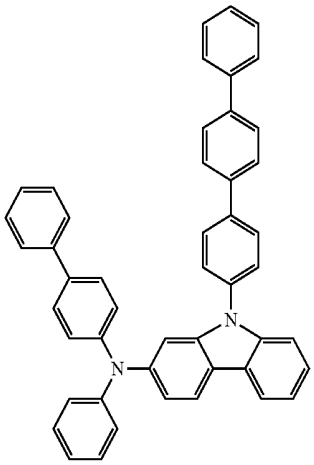

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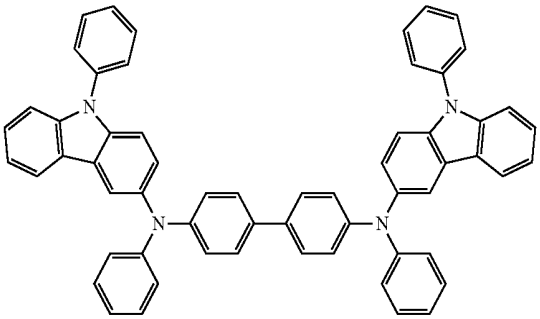

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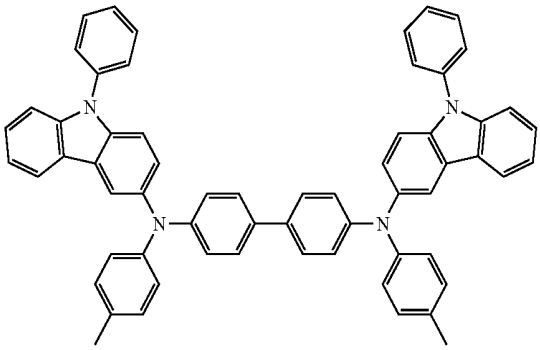

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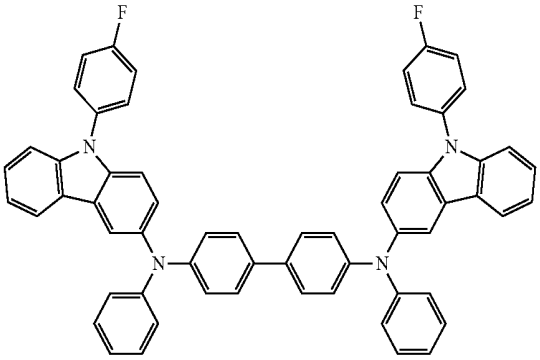

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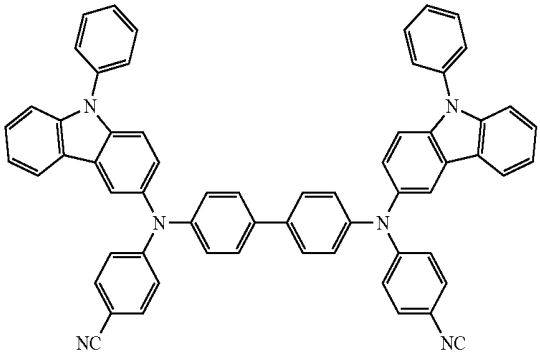

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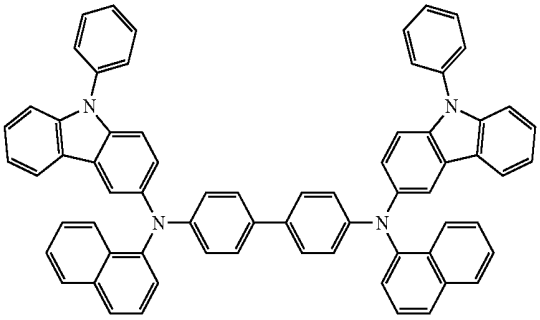

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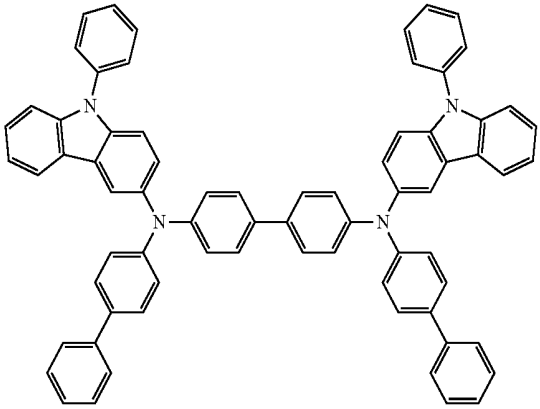

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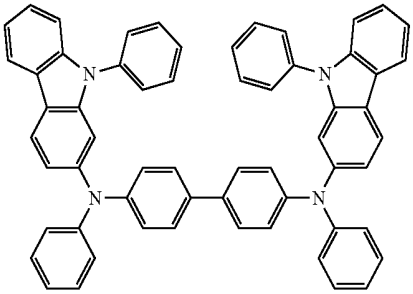

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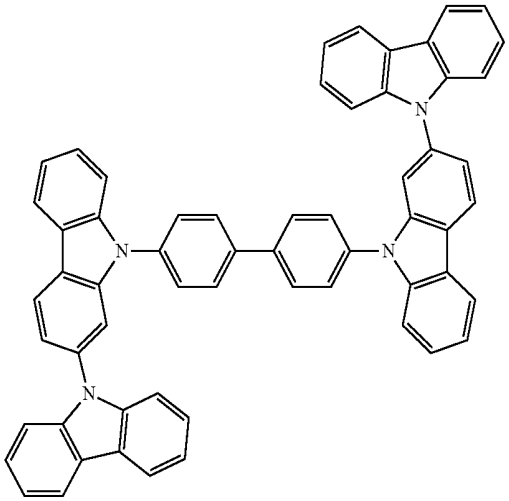

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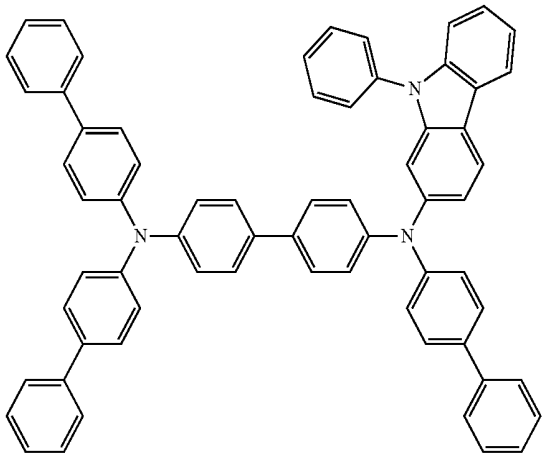

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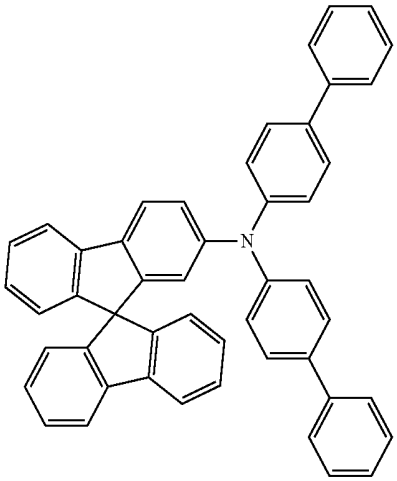

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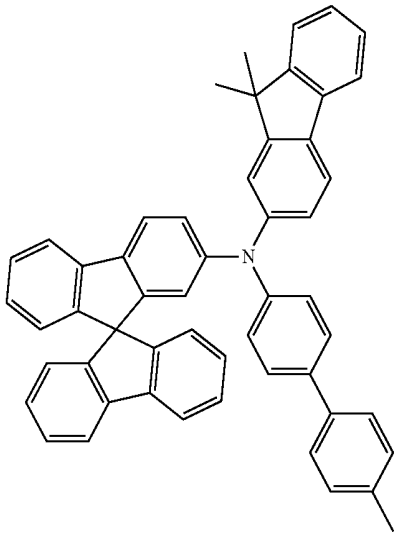
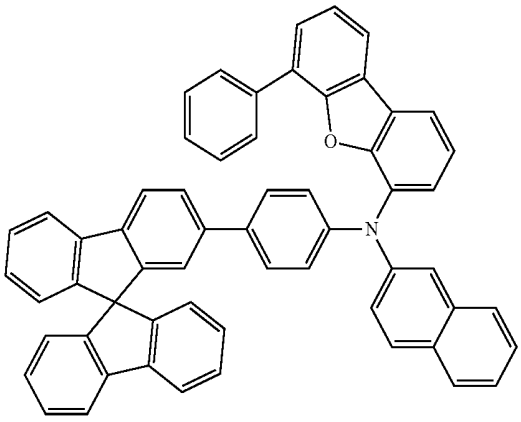


HT39



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

The emission auxiliary layer may increase light-emission efficiency by compensating for an optical resonance distance according to the wavelength of light emitted by an emission layer. The electron-blocking layer may block the flow of

electrons from an electron transport region. The emission auxiliary layer and the electron-blocking layer may include the materials described herein.

The hole transport region may include 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.

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

According to an exemplary embodiment of the present invention, a lowest unoccupied molecular orbital (LUMO) level of the p-dopant may be about −3.5 eV or less.

The p-dopant may include at least one of a quinone derivative, a metal oxide, or a compound including a cyano group; however, exemplary embodiments of the present invention are not limited thereto.

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

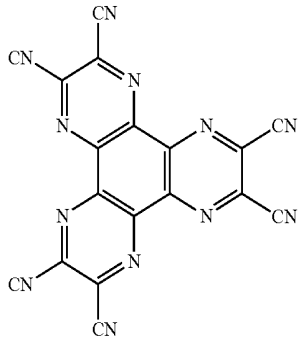
a quinone derivative, such as tetracyanoquinodimethane (TCNQ) or 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F4-TCNQ);

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

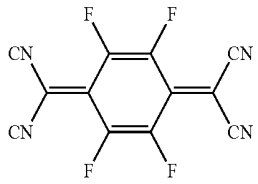
1,4,5,8,9,11-hexaazatriphenylene-hexacarbonitrile (HAT-CN); or

a compound represented by Formula 221; however, exemplary embodiments of the present invention are not limited thereto:

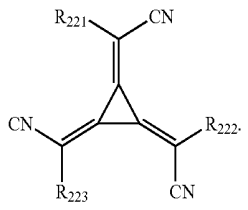
<HAT-CN>



<F4-TCNQ>



<Formula 221>



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

When the organic light-emitting device **10** is a full color organic light-emitting device, the emission layer may be patterned into a red emission layer, a green emission layer, or a blue emission layer, according to a sub-pixel. According to an exemplary embodiment of the present invention, 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. The two or more layers may be in direct contact with each other. Alternatively, the two or more layers may be separated from each other. According to an exemplary embodiment of the present invention, the emission layer may include two or more materials. The two or more materials may include a red-light emission material, a green-light emission material, or a blue-light emission material. The two or more materials may be mixed with each other in a single layer. The two or more materials mixed with each other in the single layer may emit white light.

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

An amount of the 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; however, exemplary embodiments of the present invention are not limited thereto.

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 this range, increased light-emission characteristics may be obtained without a substantial increase in driving voltage.

According to an exemplary embodiment of the present invention, the host may include a compound represented by Formula 301.

$$[Ar_{301}]_{xb11}\text{-}[(L_{301})_{xb1}\text{-}R_{301}]_{xb21} \qquad \text{<Formula 301>}$$

In Formula 301, Ar_{301} may be selected from a substituted or unsubstituted C_5-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group.

In Formula 301, xb11 may be an integer selected from 1, 2, or 3.

In Formula 301, L_{301} may be selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3-C_{10} cycloalkenylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6-C_{60} arylene group, a substituted or unsubstituted C_1-C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, or a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group.

In Formula 301, xb1 may be an integer selected from 0 to 5.

In Formula 301, R_{301} may be selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydra-

zono group, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_2-C_{60} alkynyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —$Si(Q_{301})(Q_{302})(Q_{303})$, —$N(Q_{301})(Q_{302})$, —$B(Q_{301})(Q_{302})$, —$C(=O)(Q_{301})$, —$S(=O)_2(Q_{301})$, or —$P(=O)(Q_{301})(Q_{302})$.

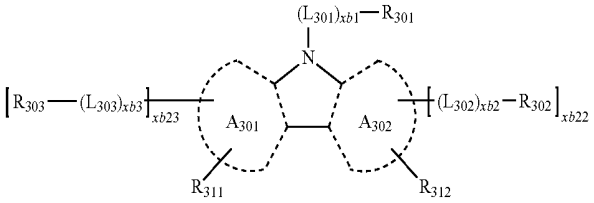
zono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, —$Si(Q_{31})(Q_{32})(Q_{33})$, —$N(Q_{31})(Q_{32})$, —$B(Q_{31})(Q_{32})$, —$C(=O)(Q_{31})$, —$S(=O)_2(Q_{31})$, or —$P(=O)(Q_{31})(Q_{32})$.

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, or a naphthyl group; however, exemplary embodiments of the present invention are not limited thereto.

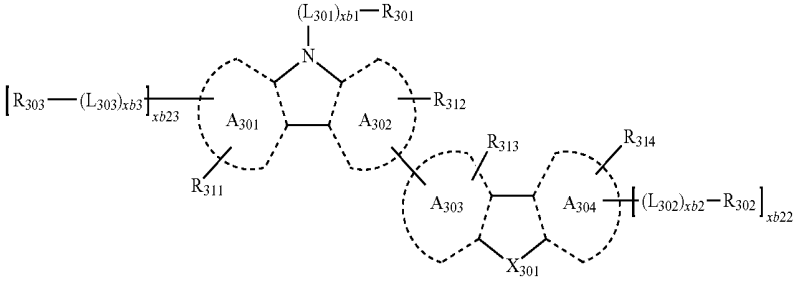
When xb11 in Formula 301 is 2 or greater, at least two Ar_{301}(s) may be linked via a single bond.

According to an exemplary embodiment of the present invention, the compound represented by Formula 301 may be represented by Formula 301-1 or Formula 301-2:

<Formula 301-1>



<Formula 301-2>



In Formula 301, xb21 may be an integer selected from 1 to 5.

In Formula 301, Q_{301} to Q_{303} 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, or a naphthyl group; however, exemplary embodiments of the present invention are not limited thereto.

According to an exemplary embodiment of the present invention, Ar_{301} in Formula 301 may be selected from:

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, naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, or a dibenzothiophene group; or

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, naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, and a dibenzothiophene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydra-

In Formulae 301-1 and 301-2, A_{301} to A_{304} may each independently be selected from a benzene, a naphthalene, a phenanthrene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a pyridine, a pyrimidine, an indene, a fluorene, a spiro-bifluorene, a benzofluorene, a dibenzofluorene, an indole, a carbazole, a benzocarbazole, a dibenzocarbazole, a furan, a benzofuran, a dibenzofuran, a naphthofuran, a benzonaphthofuran, a dinaphthofuran, a thiophene, a benzothiophene, a dibenzothiophene, a naphthothiophene, a benzonaphthothiophene, or a dinaphthothiophene.

In Formulae 301-1 and 301-2, X_{301} may be oxygen (O), sulfur (S), or N-[$(L_{304})_{xb4}$-R_{304}].

In Formulae 301-1 and 301-2, R_{311} to R_{314} 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, a naphthyl group —$Si(Q_{31})(Q_{32})(Q_{33})$, —$N(Q_{31})(Q_{32})$, —$B(Q_{31})(Q_{32})$, —$C(=O)(Q_{31})$, —$S(=O)_2(Q_{31})$, or —$P(=O)(Q_{31})(Q_{32})$,

xb22 and xb23 may each independently be an integer selected from 0, 1, or 2.

L_{301}, xb1, R_{301}, and Q_{31} to Q_{33} may be the same as described above.

L_{302} to L_{304} may each be the same as L_{301}.

xb2 to xb4 may each be the same as xb1.

R_{302} to R_{304} may each be the same as R_{301}.

According to an exemplary embodiment of the present invention, L_{301} to L_{304} in Formulae 301, 301-1, and 301-2 may each independently be selected from:

a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene 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, a pyridinylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isoxazolylene group, a thiadiazolylene group, an oxadiazolylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, or an azacarbazolylene group; or

a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene 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, a pyridinylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isoxazolylene group, a thiadiazolylene group, an oxadiazolylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an azacarbazolyl group, $—Si(Q_{31})(Q_{32})(Q_{33})$, $—N(Q_{31})(Q_{32})$, $—B(Q_{31})(Q_{32})$, $—C(=O)(Q_{31})$, $—S(=O)_2(Q_{31})$, or $—P(=O)(Q_{31})(Q_{32})$.

Q_{31} to Q_{33} may be the same as described above.

According to an exemplary embodiment of the present invention, R_{301} to R_{304} in Formulae 301, 301-1, and 301-2 may each independently be selected from:

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

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

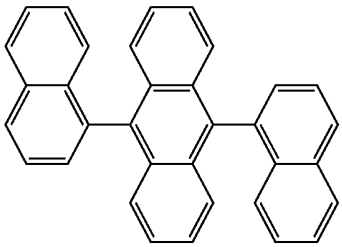
pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, 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 alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spirobifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an azacarbazolyl group, $—Si(Q_{31})(Q_{32})(Q_{33})$, $—N(Q_{31})(Q_{32})$, $—B(Q_{31})(Q_{32})$, $—C(=O)(Q_{31})$, $—S(=O)_2(Q_{31})$, or $—P(=O)(Q_{31})(Q_{32})$.

Q_{31} to Q_{33} may be the same as described above.

According to an exemplary embodiment of the present invention, the host may include an alkaline-earth metal complex. For example, the host may include a beryllium (Be) complex, for example, Compound H55, a magnesium (Mg) complex, or a zinc (Zn) complex.

The host may include at least one of 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), or Compounds H1 to H55; however, exemplary embodiments of the present invention are not limited thereto.

H1



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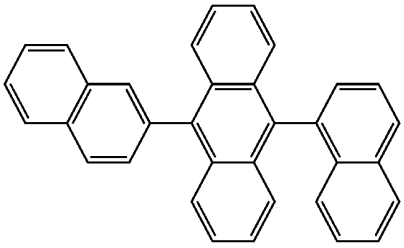
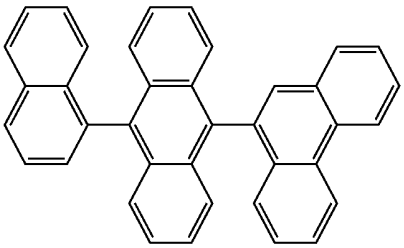
H2



H3



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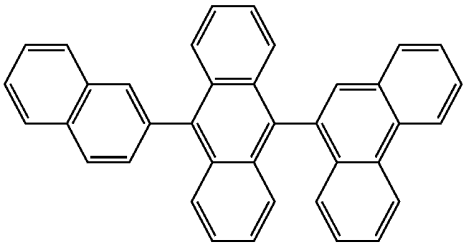
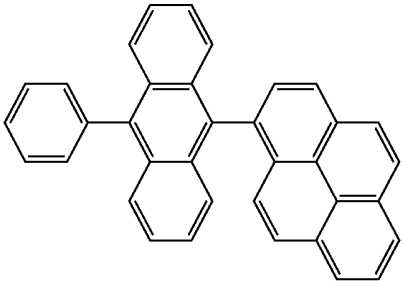


H5



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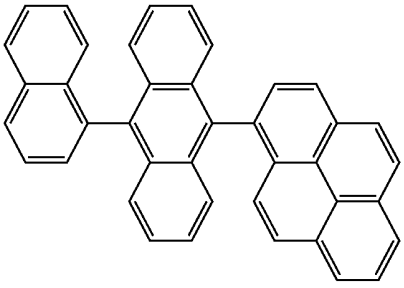

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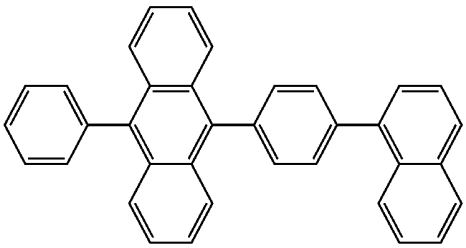

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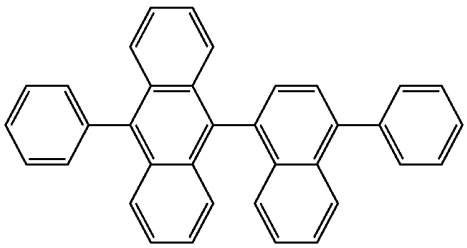
H8



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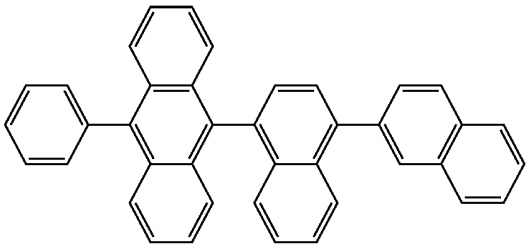

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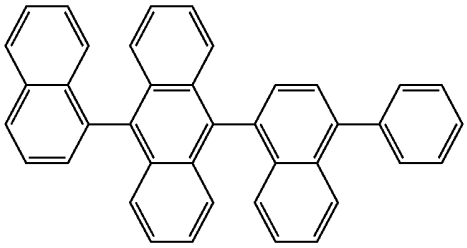

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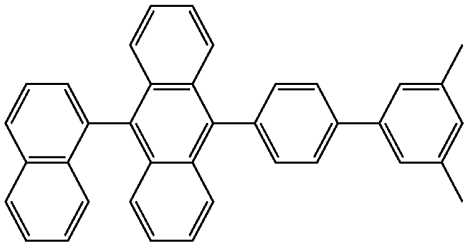

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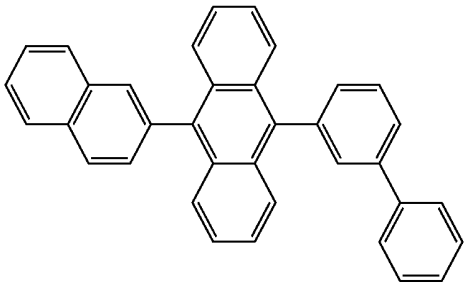

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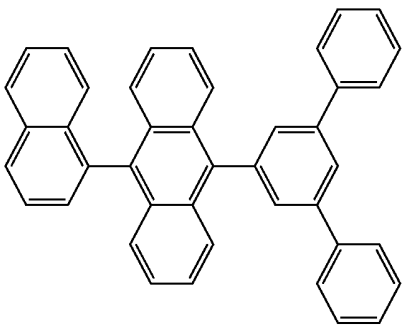

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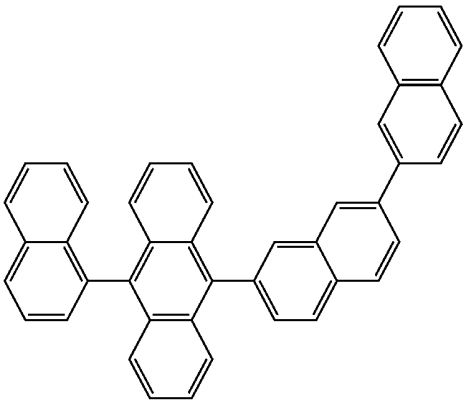

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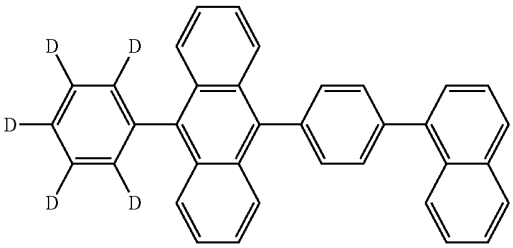

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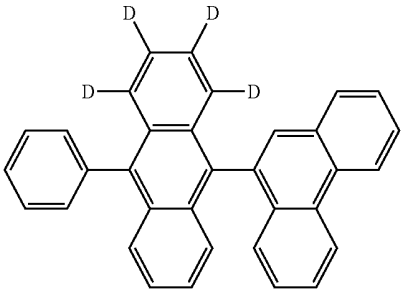

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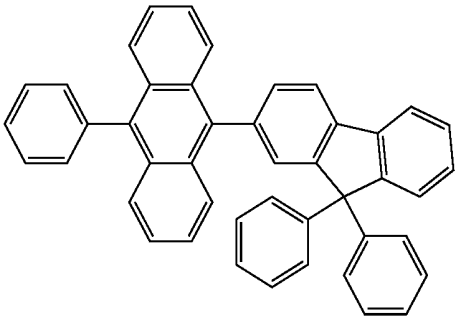

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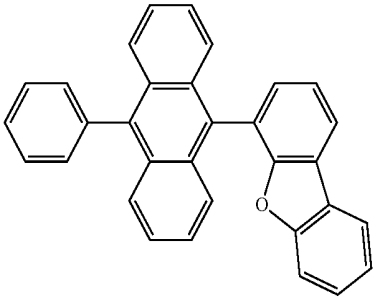

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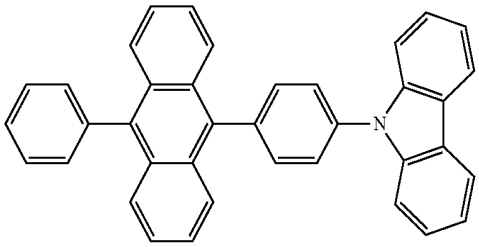

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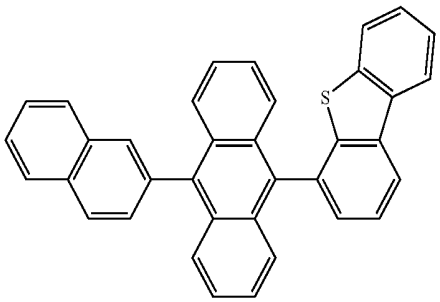

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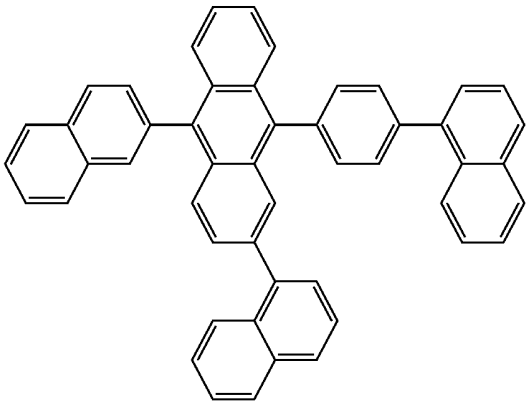

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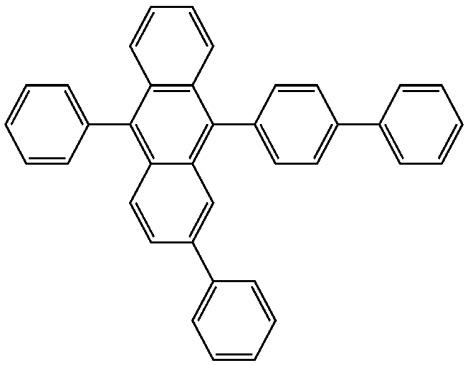

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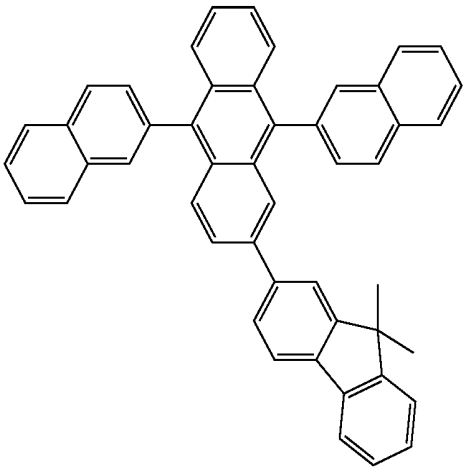

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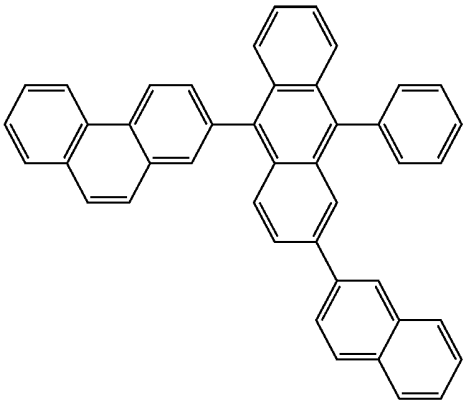

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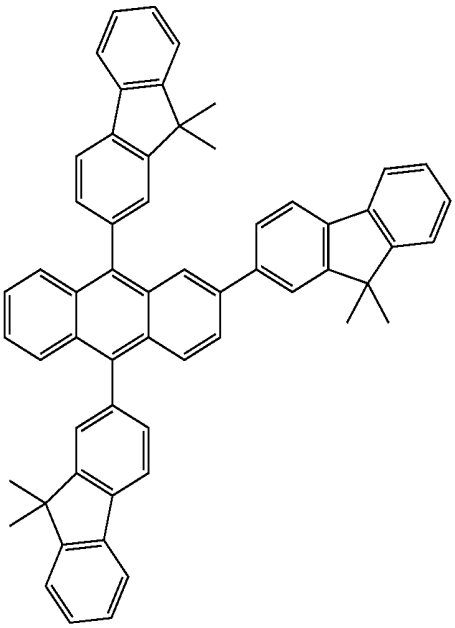

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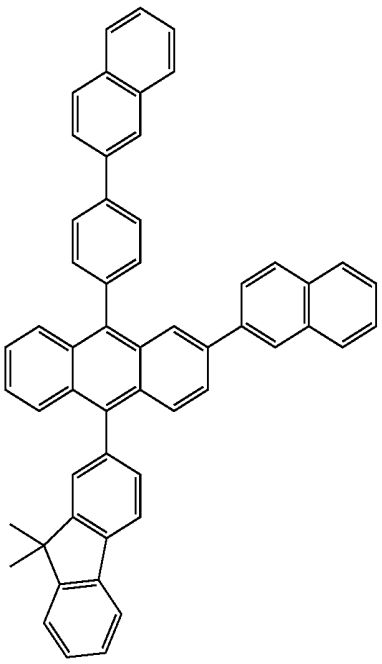

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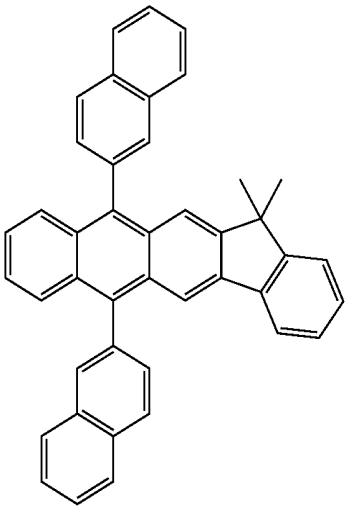

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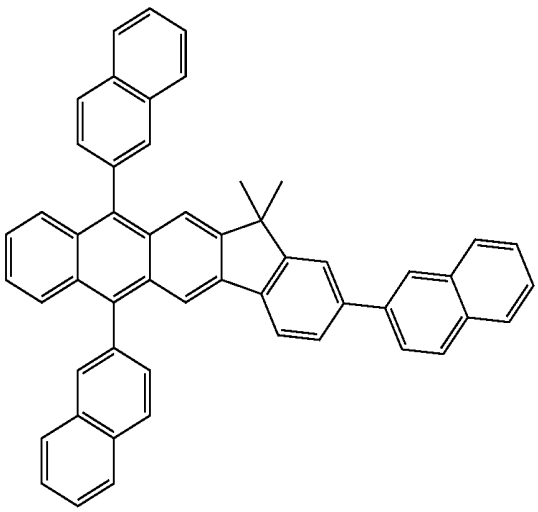

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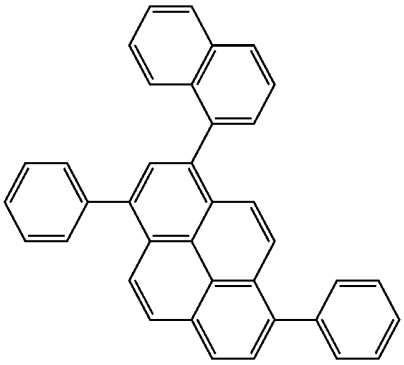

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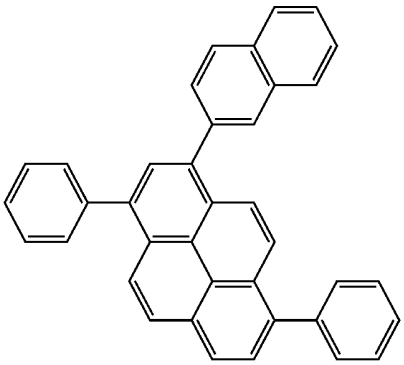

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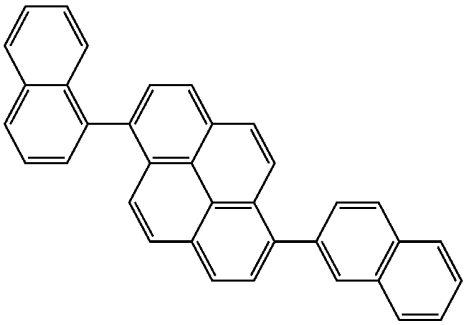

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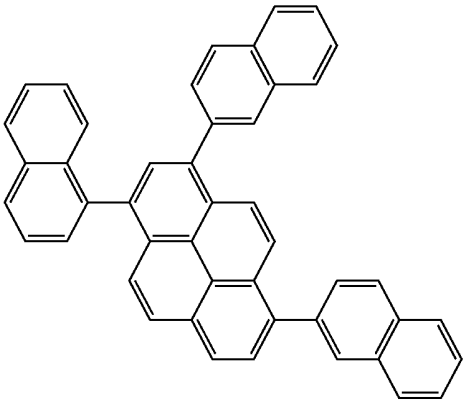

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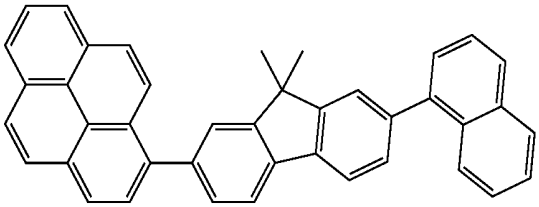

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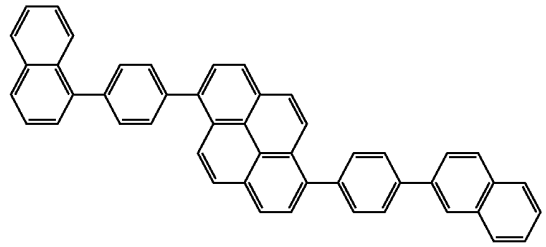
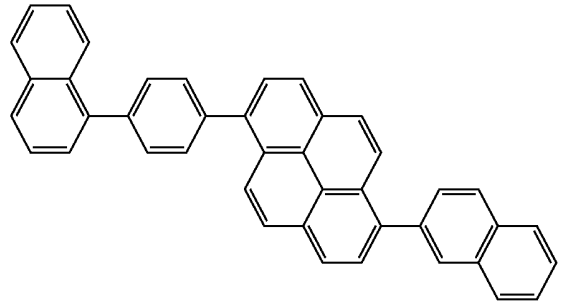
H34



H35



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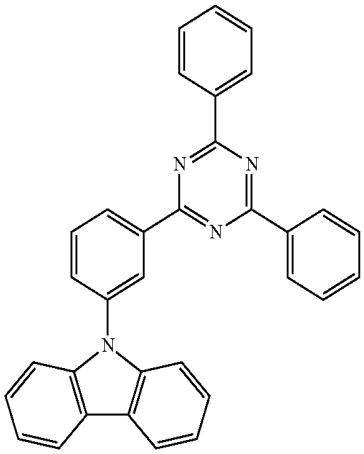

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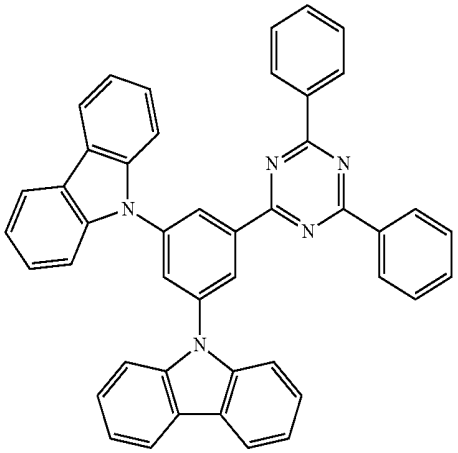

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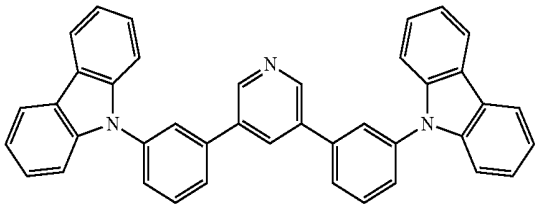

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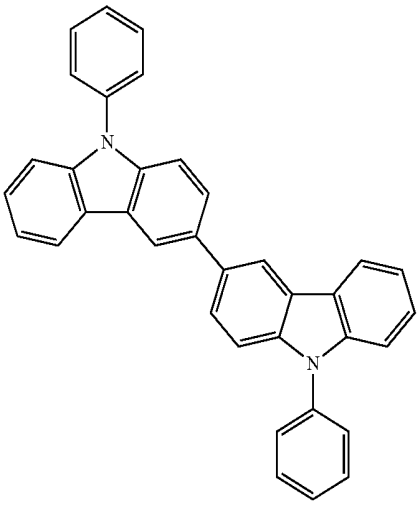

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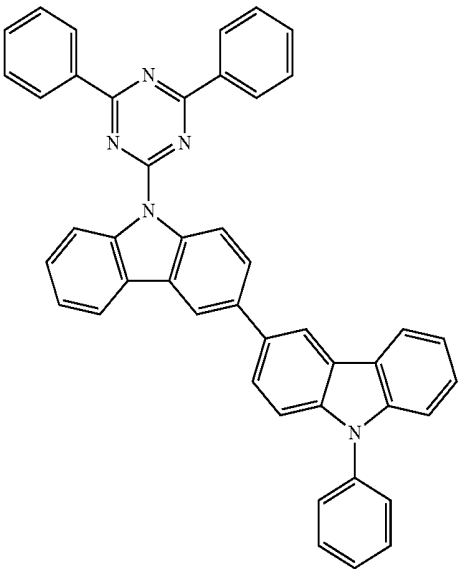

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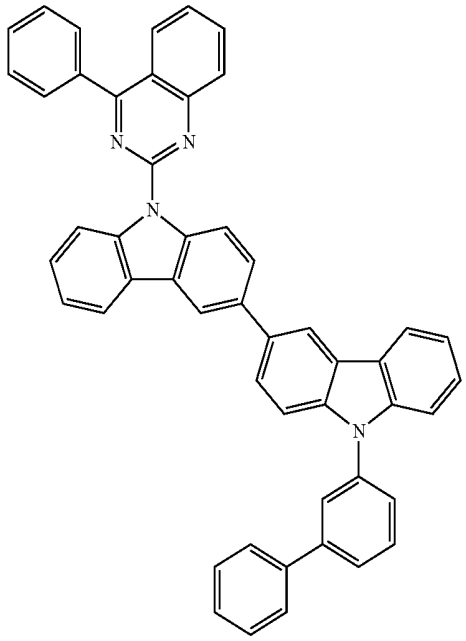

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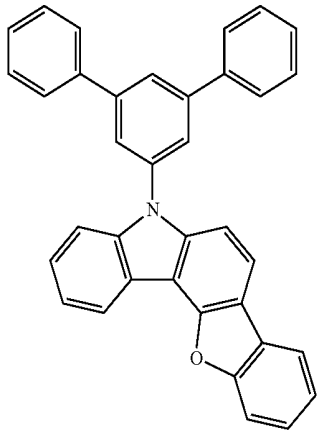

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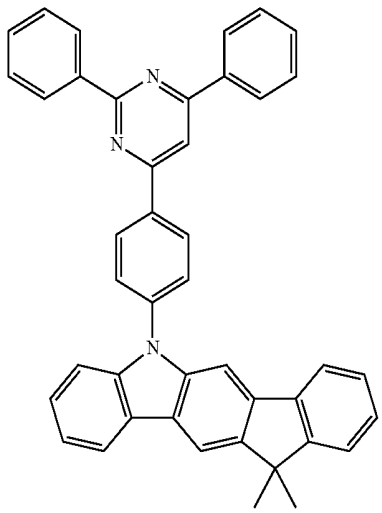

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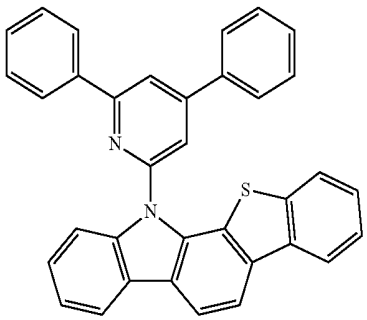

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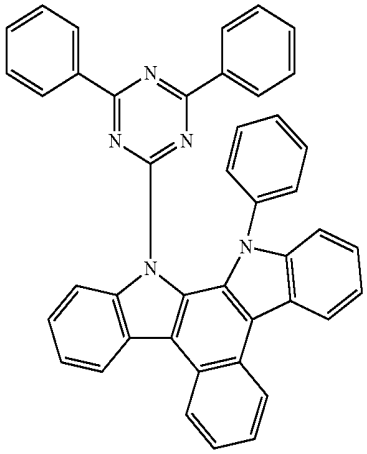

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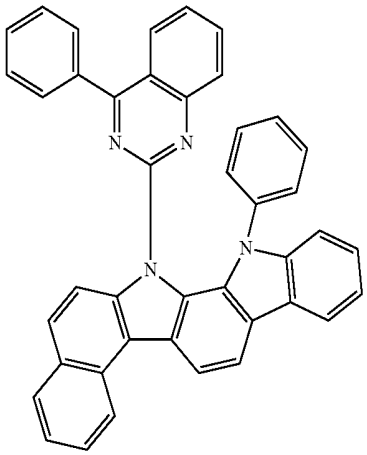

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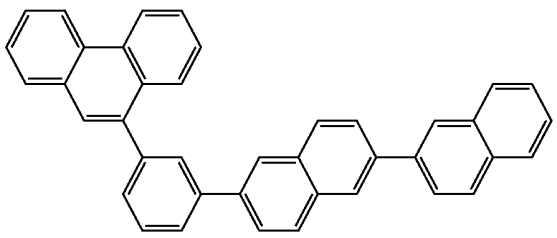

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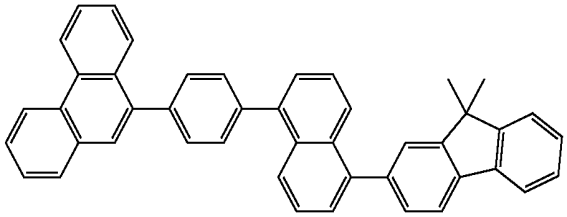

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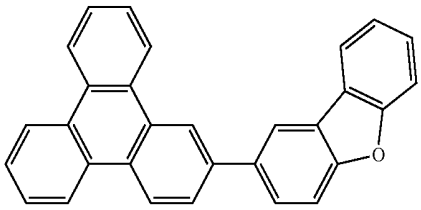

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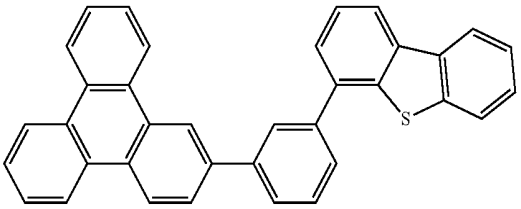

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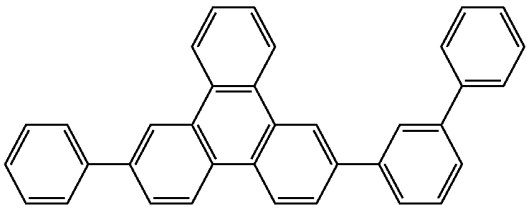

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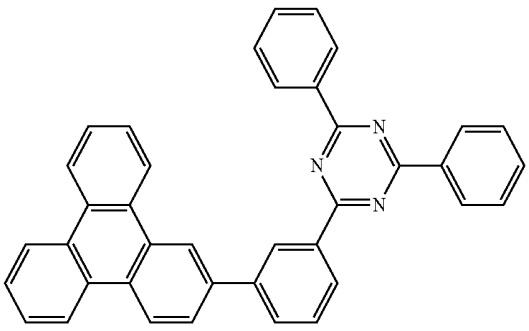

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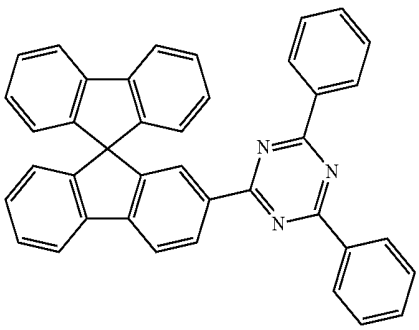

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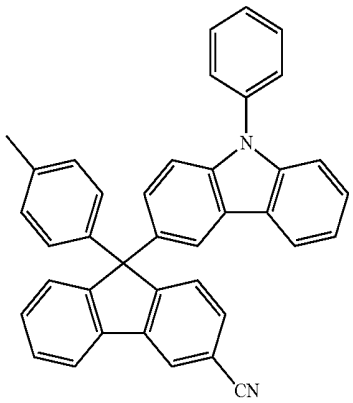
H54



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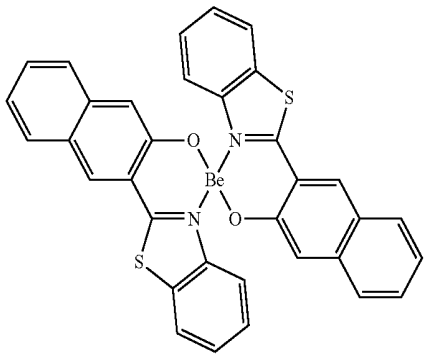
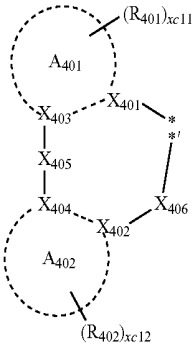


The phosphorescent dopant may include an organometallic complex represented by Formula 401:

$$M(L_{401})_{xc1}(L_{402})_{xc2} \quad \text{<Formula 401>}$$

<Formula 402>



In Formulae 401 and 402, 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), or thulium (Tm).

In Formulae 401 and 402, L_{401} may be selected from ligands represented by Formula 402. xc1 may be an integer selected from 1, 2, or 3. When xc1 is 2 or greater, at least two L_{401}(s) may be the same or different from each other.

In Formulae 401 and 402, L_{402} may be an organic ligand. xc2 may be an integer selected from 0 to 4. When xc2 is 2 or greater, at least two L_{402}(s) may be the same or different from each other.

In Formulae 401 and 402, X_{401} to X_{404} may each independently be selected from nitrogen (N) or carbon (C).

In Formulae 401 and 402, X_{401} and X_{403} may be linked via a single bond or a double bond. X_{402} and X_{404} may be linked via a single bond or a double bond.

In Formulae 401 and 402, A_{401} and A_{402} may each independently be selected from a C_5-C_{60} carbocyclic group or a C_1-C_{60} heterocyclic group.

In Formulae 401 and 402, X_{405} may be selected from a single bond, *—O—*', *—S—*', *—C(=O)—*', *—N(Q_{411})-*', *—C(Q_{411})(Q_{412})-*', *—C(Q_{411})=C(Q_{412})-*', *—C(Q_{411})=*', or *=C(Q_{411})=*'. Q_{411} and Q_{412} may be selected from hydrogen, deuterium, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group.

In Formulae 401 and 402, X_{406} may be selected from a single bond, oxygen (O), or sulfur (S).

In Formulae 401 and 402, R_{401} and R_{402} 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_{20} alkyl group, a substituted or unsubstituted C_1-C_{20} 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, —Si(Q_{401})(Q_{402})(Q_{403}), —N(Q_{401})(Q_{402}), —B(Q_{401})(Q_{402}), —C(=O)(Q_{401}), —S(=O)$_2$(Q_{401}) and —P(=O)(Q_{401})(Q_{402}), wherein Q_{401} to Q_{403} may each independently be selected from a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a C_6-C_{20} aryl group, or a C_1-C_{20} heteroaryl group.

In Formulae 401 and 402, xc11 and xc12 may each independently be an integer selected from 0 to 10.

In Formulae 401 and 402, * and *' in Formula 402 may each indicate a binding site to M in Formula 401.

According to an exemplary embodiment of the present invention, A_{401} and A_{402} 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 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, or a dibenzothiophene group.

In Formula 402, X_{401} may be nitrogen (N) and X_{402} may be carbon (C). Alternatively, X_{401} and X_{402} may each be nitrogen (N).

According to an exemplary embodiment of the present invention, R_{401} and R_{402} in Formula 402 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, or a C_1-C_{20} alkoxy group;

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, 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, or a norbornenyl 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 quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, or a dibenzothiophenyl 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 quinazolinyl 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 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 dibenzofuranyl group, or a dibenzothiophenyl group; or

—Si(Q_{401})(Q_{402})(Q_{403}), —N(Q_{401})(Q_{402}), —B(Q_{401})(Q402), —C(=O)(Q_{401}), —S(=O)$_2$(Q_{401}), or —P(=O)(Q_{401})(Q_{402}).

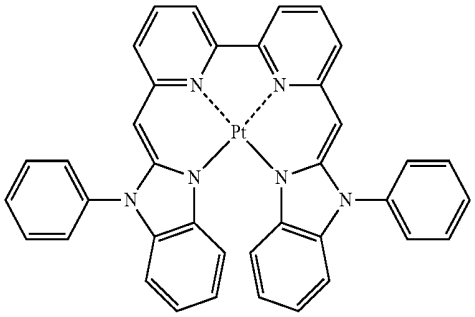
Q_{401} to Q_{403} may each independently be selected from a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, or a naphthyl group; however, exemplary embodiments of the present invention are not limited thereto.

According to an exemplary embodiment of the present invention, when xc1 in Formula 401 is 2 or greater, two A_{401}(s) in at least two L_{401}(s) may be linked via X_{407}, which is a linking group. Alternatively, two A_{402}(s) in at least two L_{401}(s) may be linked via X_{408}, which is a linking group (see, e.g., Compounds PD1 to PD4 and PD7). X_{407} and X_{408} may each independently be selected from a single bond, *—O—*', *—S—*', *—C(=O)—*', *—N(Q_{413})-*', *—C(Q_{413})(Q_{414})-*', or *—C(Q_{413})=C(Q_{414})-*', in which Q_{413} and Q_{414} may each independently be selected from hydrogen, deuterium, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group; however, exemplary embodiments of the present invention are not limited thereto.

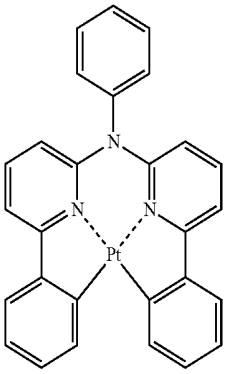
L_{402} in Formula 401 may be a monovalent, divalent, or trivalent organic ligand. For example, L_{402} may be selected from halogen, diketone (for example, acetylacetonate), carboxylic acid (for example, picolinate), —C(=O), isonitrile, —CN, or phosphorus (for example, phosphine or phosphite); however, exemplary embodiments of the present invention are not limited thereto.

According to one or more exemplary embodiments of the present invention, the phosphorescent dopant may be selected from, for example, Compounds PD1 to PD25; however, exemplary embodiments of the present invention are not limited thereto:

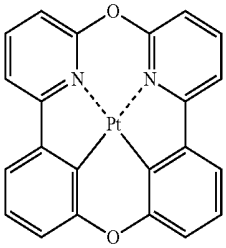
PD1



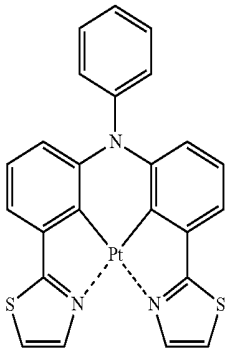
PD2



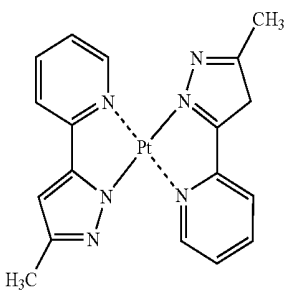
PD3



PD4



PD5



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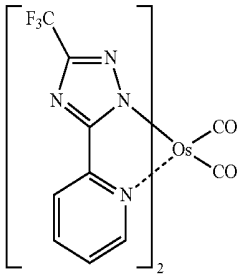
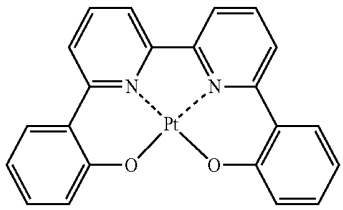
PD6



PD7



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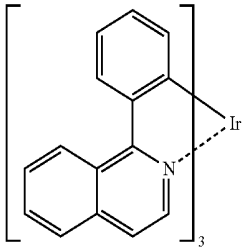

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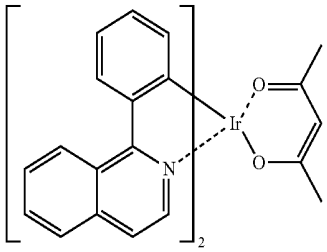

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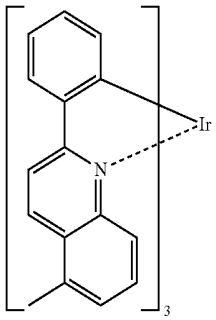

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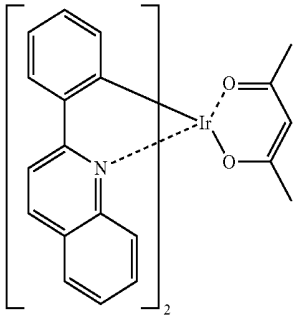

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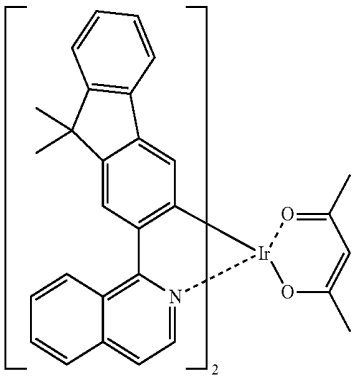
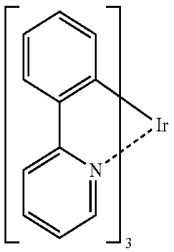
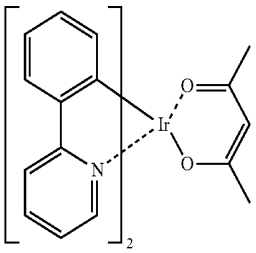
PD12



PD13



PD14



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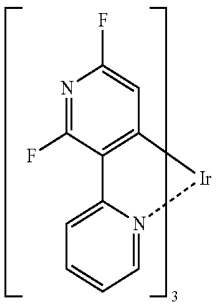

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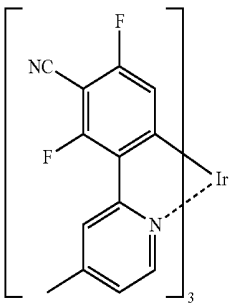

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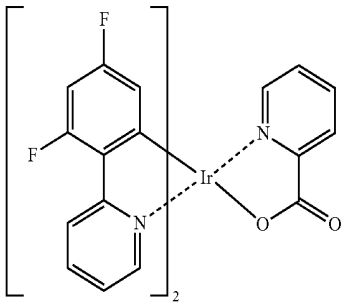
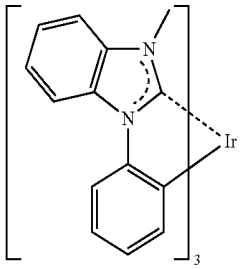
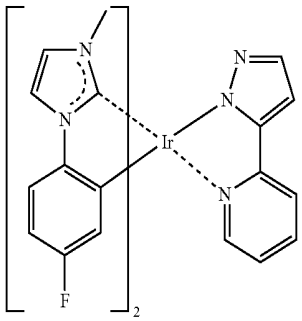
PD17



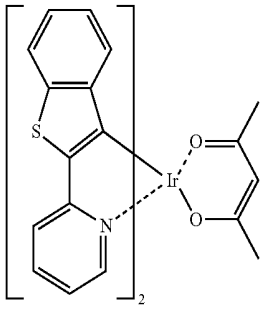
PD18



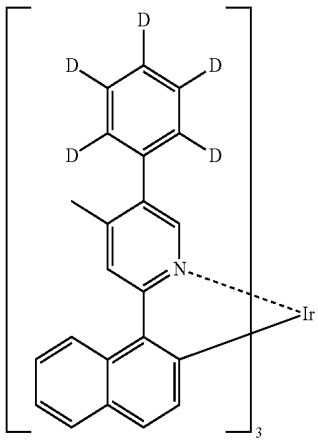
PD19



PD20



PD21



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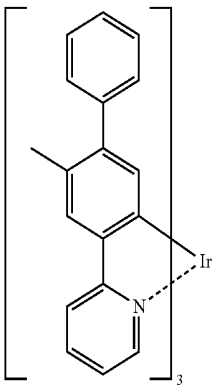
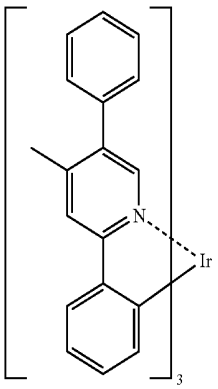
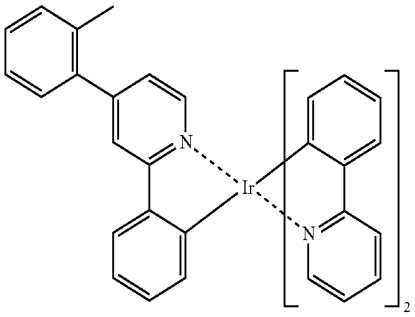
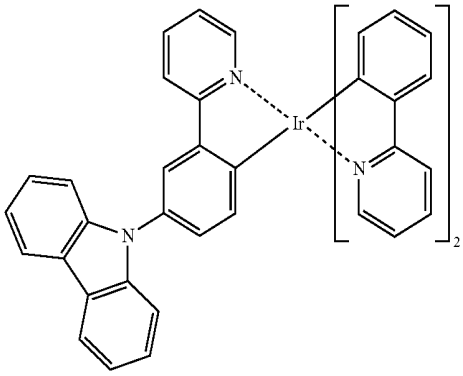




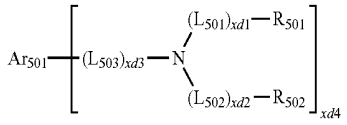




According to one or more exemplary embodiments of the present invention, a fluorescent dopant may include an arylamine compound or a styrylamine compound.

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

PD22



<Formula 501>

In Formula 501, Ar_{501} may be selected from a substituted or unsubstituted C_5-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group.

In Formula 501, 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, or a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group.

PD23

In Formula 501, xd1 to xd3 may each independently be an integer selected from 0 to 3.

In Formula 501, 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} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, or a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group.

PD24

In Formula 501, xd4 may be an integer selected from 1 to 6.

According to an exemplary embodiment of the present invention, Ar_{501} in Formula 501 may be selected from:

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, or an indenophenanthrene group; or

PD25

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, or a naphthyl group.

According to an exemplary embodiment of the present invention, L_{501} to L_{503} in Formula 501 may each independently be selected from:

a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene

group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene 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, or a pyridinylene group; or

a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene 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 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, or a pyridinyl group.

According to an exemplary embodiment of the present invention, R_{501} and R_{501} in Formula 502 may each independently be selected from:

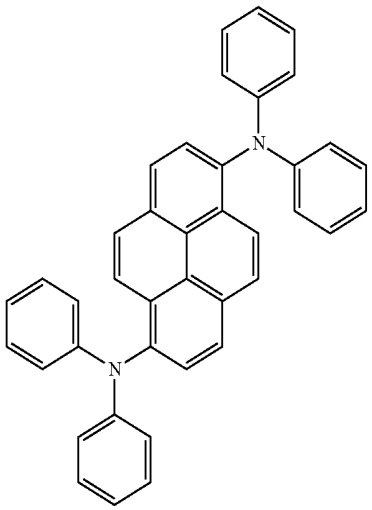
a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, or a pyridinyl group; or

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, 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 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, or —$Si(Q_{31})(Q_{32})(Q_{33})$. 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, or a naphthyl group.

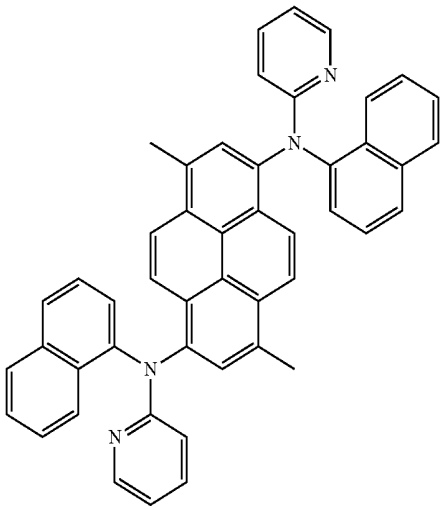
xd4 in Formula 501 may be 2; however, exemplary embodiments of the present invention are not limited thereto.

For example, the fluorescent dopant may be selected from Compounds FD1 to FD22:

FD1



FD2



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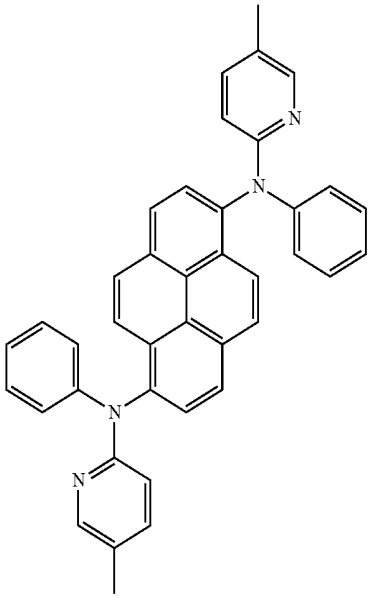
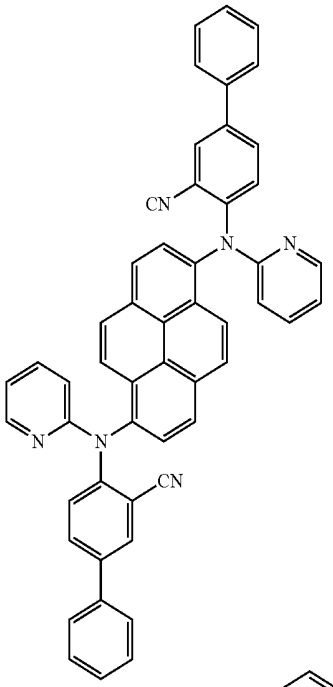
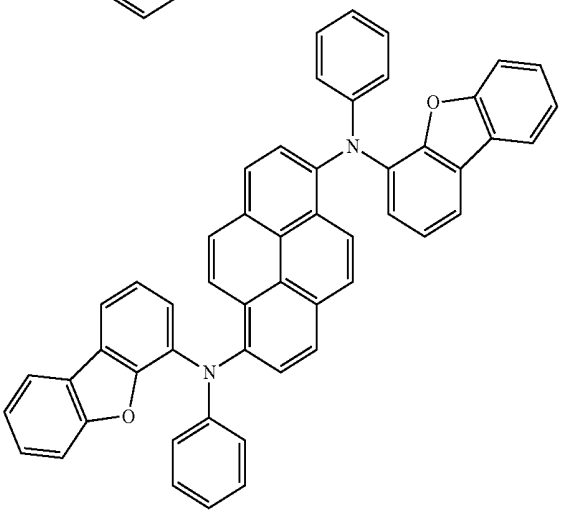
FD3



FD4



FD5



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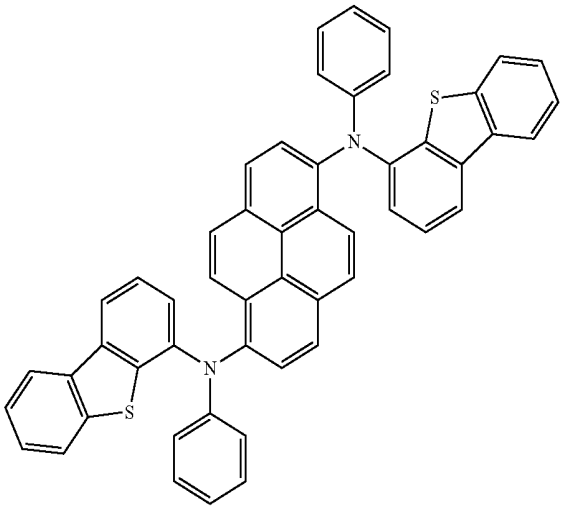
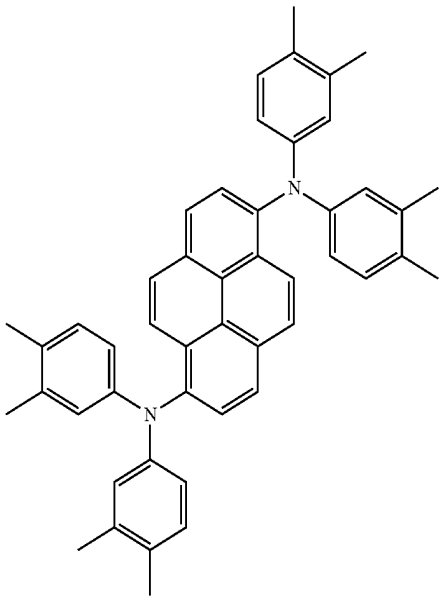
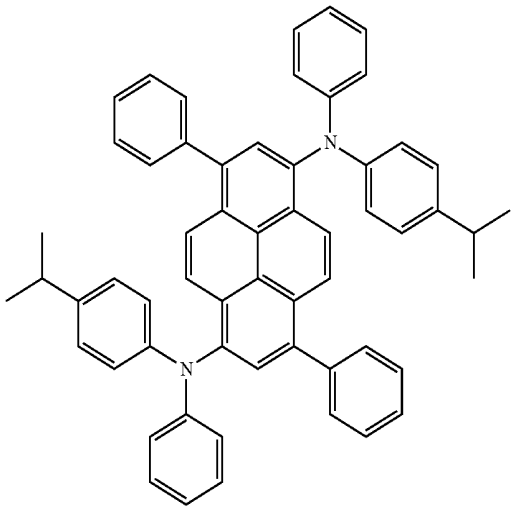
FD6



FD7



FD8



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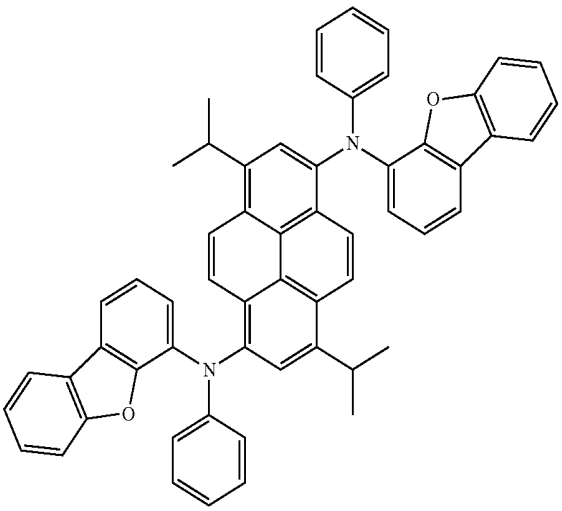
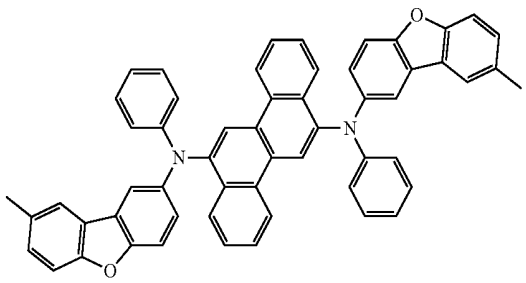
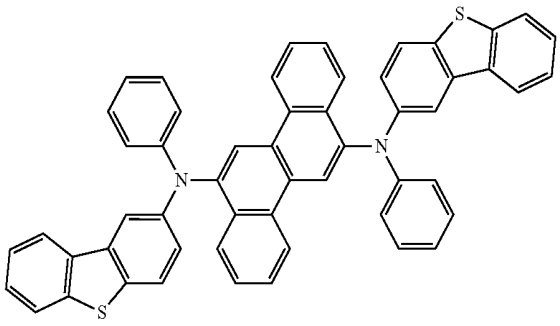
FD9



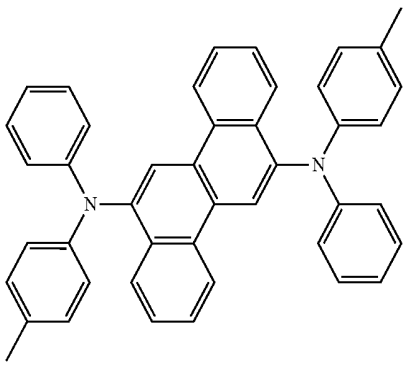
FD10



FD11



FD12



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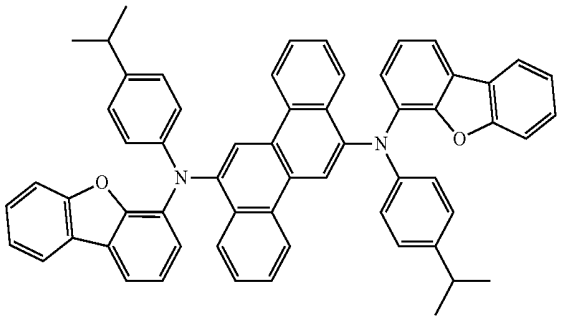
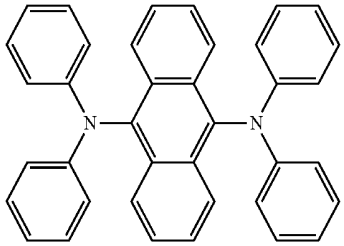
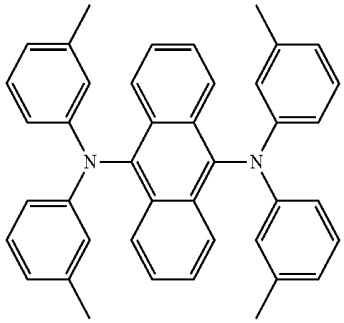
FD13



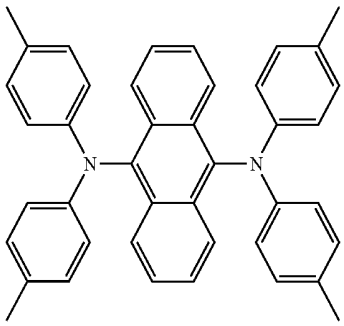
FD14



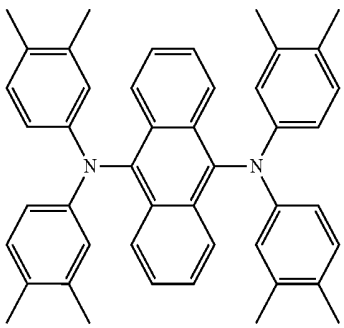
FD15



FD16



FD17



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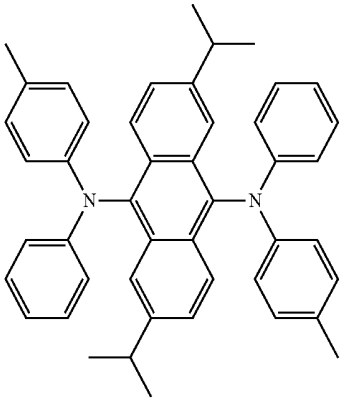
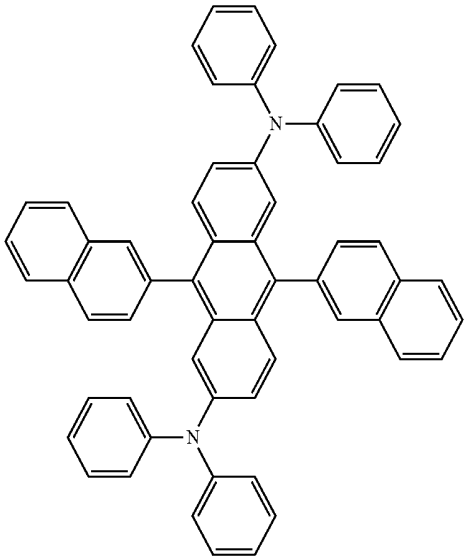
FD18



FD19



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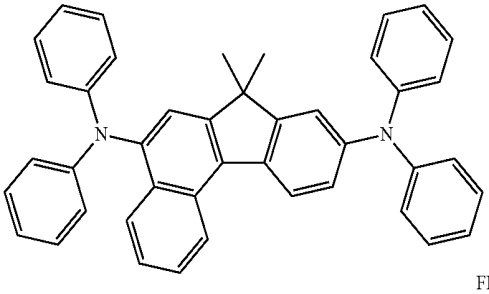
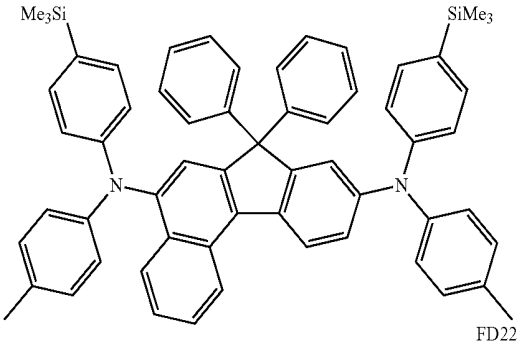
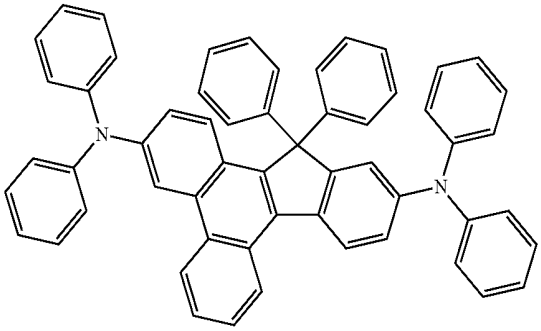
FD20



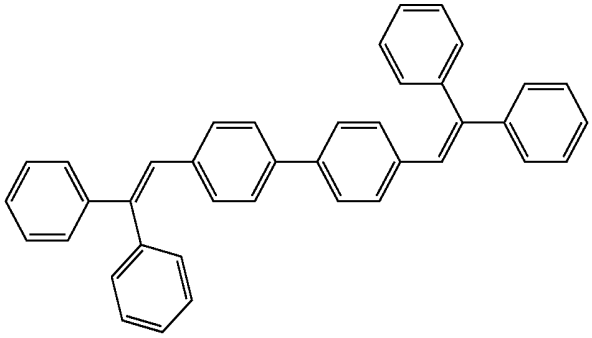
FD21



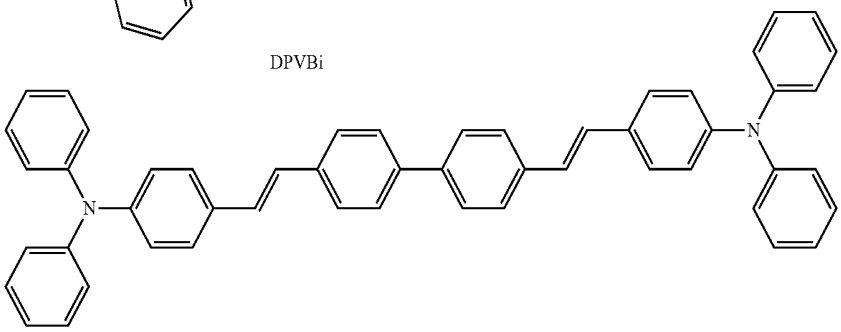
FD22



The fluorescent dopant may be selected from the following compounds; however, exemplary embodiments of the present invention are not limited thereto.



DPVBi



DPAVBi

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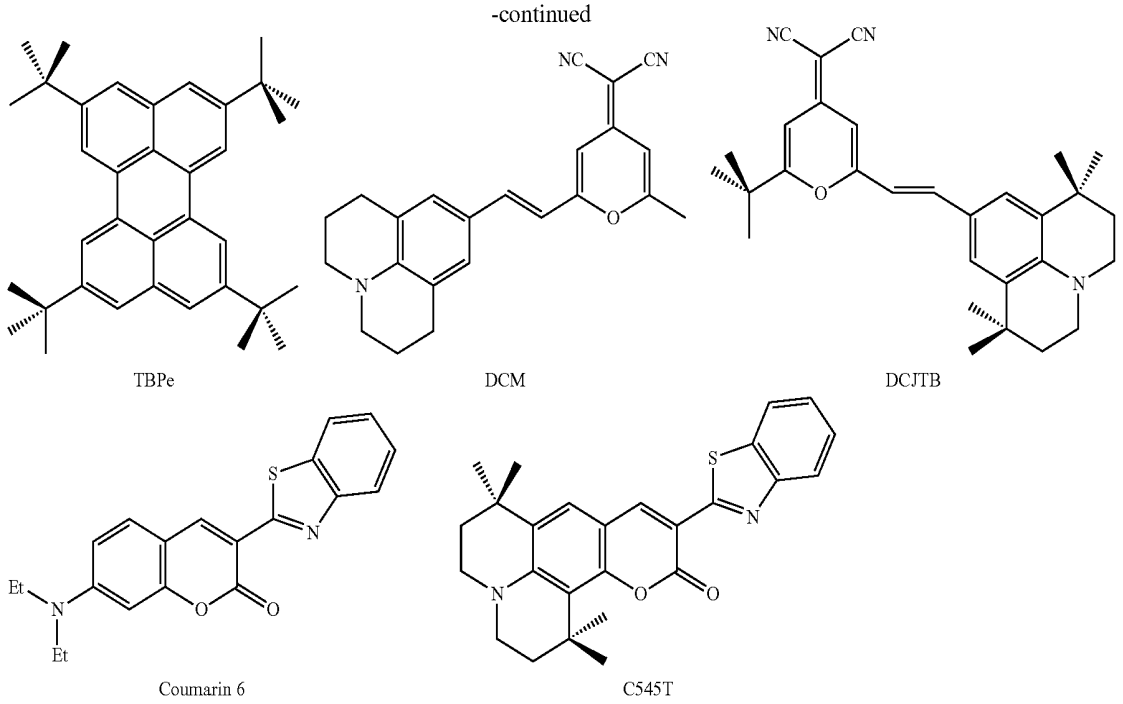


TBPe DCM DCJTB

Coumarin 6 C545T

The electron transport region may have a single-layered structure including a single layer including a single material. The electron transport region may have a single-layered structure including a single layer including a plurality of different materials. The electron transport region may have a multi-layered structure having a plurality of layers including a plurality of different materials.

The electron transport region may include at least one of a buffer layer, a hole blocking layer, an electron control layer, an electron transport layer, or an electron injection layer; however, exemplary embodiments of the present invention are not limited thereto.

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 an emission layer. However, exemplary embodiments of the structure of the electron transport region are not limited thereto.

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. The metal free-compound may include at least one π electron-depleted ring including nitrogen.

The π electron-depleted ring including nitrogen may indicate a C_1-C_{60} heterocyclic group having at least one *—N=*' moiety as a ring-forming moiety.

For example, the π electron-depleted ring including nitrogen may be a 5-membered to 7-membered hetero monocyclic group having at least one *—N=*' moiety. The π electron-depleted ring including nitrogen may be a heteropoly cyclic group in which two or more 5-membered to 7-membered hetero monocyclic groups each having at least one *—N=*' moiety are condensed with each other. The π electron-depleted ring including nitrogen may be a heteropoly cyclic group in which at least one of 5-membered to 7-membered hetero monocyclic groups, each having at least one *—N=*' moiety, is condensed with at least one C_5-C_{60} carbocyclic group.

Examples of the π electron-depleted ring including nitrogen include an imidazole, a pyrazole, a thiazole, an isothiazole, an oxazole, an isoxazole, a pyridine, a pyrazine, a pyrimidine, a pyridazine, an indazole, a purine, a quinoline, an isoquinoline, a benzoquinoline, a phthalazine, a naphthyridine, a quinoxaline, a quinazoline, a cinnoline, a phenanthridine, an acridine, a phenanthroline, a phenazine, a benzimidazole, an isobenzothiazole, a benzoxazole, an isobenzoxazole, a triazole, a tetrazole, an oxadiazole, a triazine, thiadiazol, an imidazopyridine, an imidazopyrimidine, or an azacarbazole; however, exemplary embodiments of the present invention are not limited thereto.

According to an exemplary embodiment of the present invention, the electron transport region may include, in addition to the condensed cyclic compound represented by Formula 1, a compound represented by Formula 601.

$$[Ar_{601}]_{xe11}\text{-}[(L_{601})_{xe1}\text{-}R_{601}]_{xe21}. \qquad \text{<Formula 601>}$$

In Formula 601, Ar_{601} may be selected from a substituted or unsubstituted C_5-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group.

In Formula 601, xe11 may be an integer selected from 1, 2, or 3.

In Formula 601, L_{601} may be selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3-C_{10} cycloalkenylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6-C_{60} arylene group, a substituted or unsubstituted C_1-C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, or a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group.

In Formula 601, xe1 may be an integer selected from 0 to 5.

In Formula 601, R_{601} may be selected from a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —$Si(Q_{601})(Q_{602})(Q_{603})$, —$C(=O)(Q_{601})$, —$S(=O)_2(Q_{601})$, or —$P(=O)(Q_6)(Q_{602})$.

In Formula 601, Q_{601} to Q_{603} 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, or a naphthyl group.

In Formula 601, xe21 may be an integer selected from 1 to 5.

According to an exemplary embodiment of the present invention, in Formula 601, at least one of Ar_{601}(s) in the number of xe11 and/or at least one of R_{601}(s) in the number of xe21 may include the π electron-depleted ring including nitrogen.

According to an exemplary embodiment of the present invention, the ring Ar_{601} in Formula 601 may be selected from:

a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, 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, a phenanthroline group, a phenazine group, a benzimidazole group, an iso-benzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, thiadiazol group, an imidazopyridine group, an imidazopyrimidine group, or an azacarbazole group; or

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, 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, a phenanthroline group, a phenazine group, a benzimidazole group, an iso-benzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, thiadiazol group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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, —$Si(Q_{31})(Q_{32})(Q_{33})$, —$S(=O)_2(Q_{31})$, or —$P(=O)(Q_{31})(Q_{32})$.

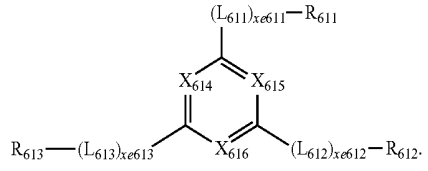
Q_{31} to Q_{33} may each independently be selected from a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group.

When xe11 in Formula 601 is 2 or greater, at least two Ar_{601}(s) may be linked via a single bond.

According to an exemplary embodiment of the present invention, Ar_{601} in Formula 601 may be an anthracene group.

According to an exemplary embodiment of the present invention, the compound represented by Formula 601 may be represented by Formula 601-1:

<Formula 601-1>



In Formula 601-1, X_{614} may be nitrogen (N) or $C(R_{614})$, X_{615} may be nitrogen (N) or $C(R_{615})$, X_{616} may be nitrogen (N) or $C(R_{616})$, and at least one of X_{614} to X_{616} may be nitrogen (N).

In Formula 601-1, L_{611} to L_{613} may each independently be substantially the same as described with reference to L_{601}.

In Formula 601-1, xe611 to xe613 may each independently be substantially the same as described with reference to xe1.

In Formula 601-1, R_{611} to R_{613} may each independently be substantially the same as described with reference to R_{601}.

In Formula 601-1, 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, or a naphthyl group.

According to an exemplary embodiment of the present invention, L_{601} and L_{611} to L_{613} in Formulae 601 and 601-1 may each independently be selected from:

a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene 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, a pyridinylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isox-

azolylene group, a thiadiazolylene group, an oxadiazolylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, or an azacarbazolylene group; or

a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene 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, a pyridinylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isoxazolylene group, a thiadiazolylene group, an oxadiazolylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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, 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, or an azacarbazolyl group; however, exemplary embodiments of the present invention are not limited thereto.

According to an exemplary embodiment of the present invention, xe1 and xe611 to xe613 in Formulae 601 and 601-1 may each independently be an integer selected from 0, 1, or 2.

According to an exemplary embodiment of the present invention, R_{601} and R_{611} to R_{613} in Formula 601 and 601-1 may each independently be selected from:

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

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

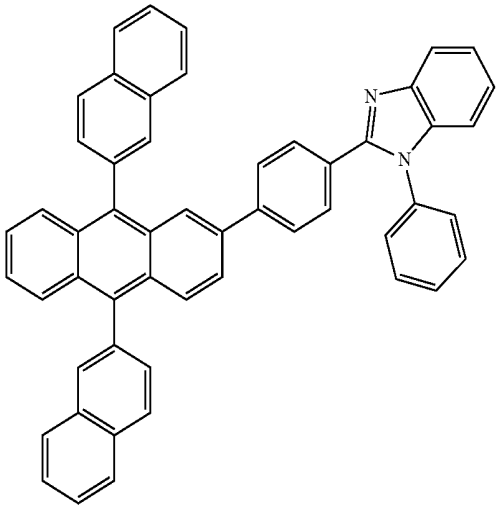
phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, each substituted with at least one selected from deuterium, —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, 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, or an azacarbazolyl group; or

—$S(=O)_2(Q_{601})$ and —$P(=O)(Q_{601})(Q_{602})$.

Q_{601} and Q_{602} may be the same as described above.

The electron transport region may include at least one compound selected from Compounds ET1 to ET36; however, exemplary embodiments of the present invention are not limited thereto:

ET1



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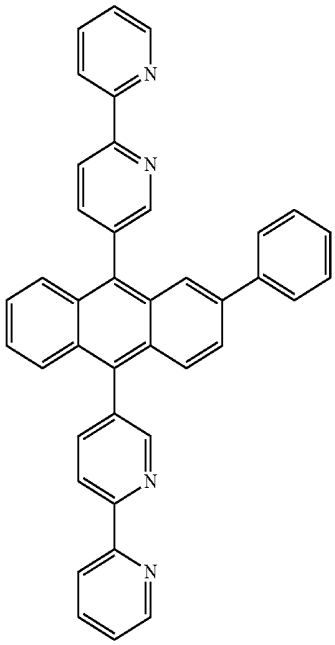
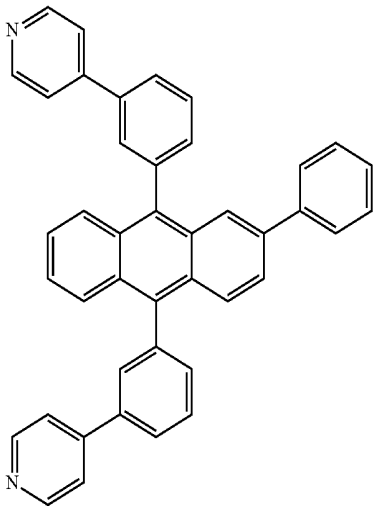
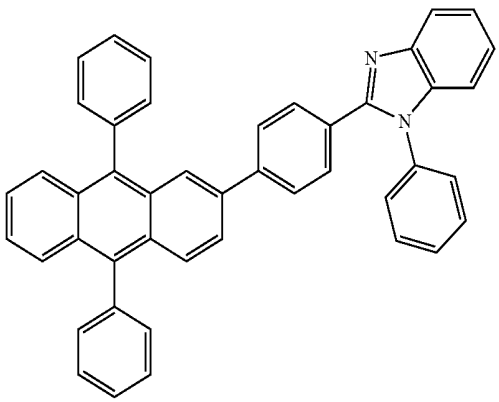
ET2



ET3



ET4



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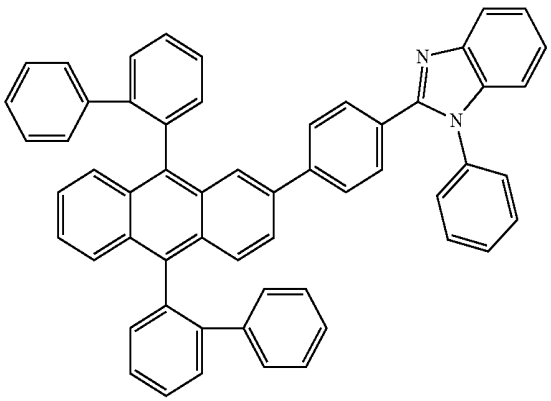
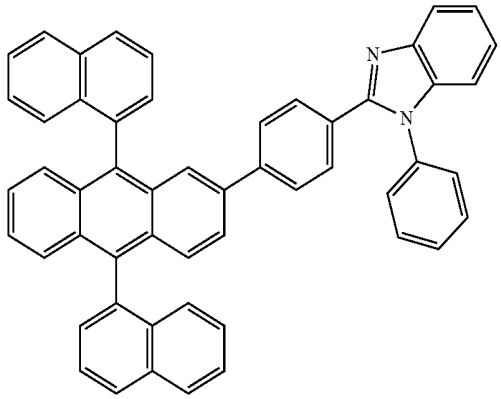
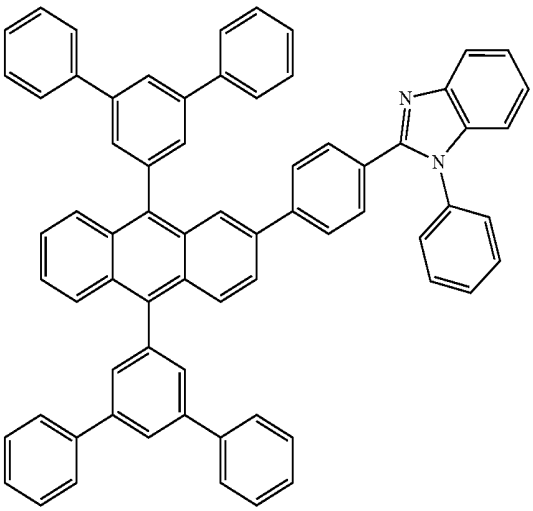
ET5



ET6



ET7



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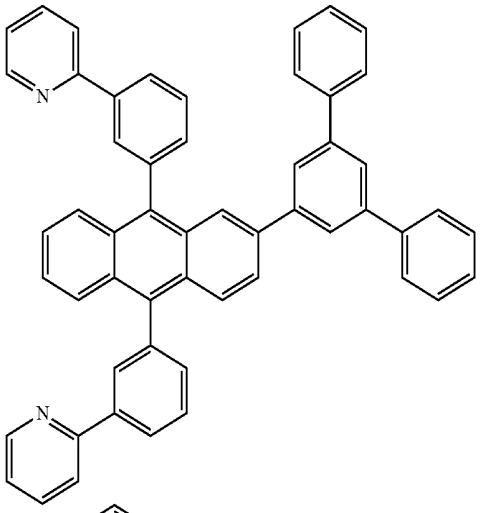
ET8



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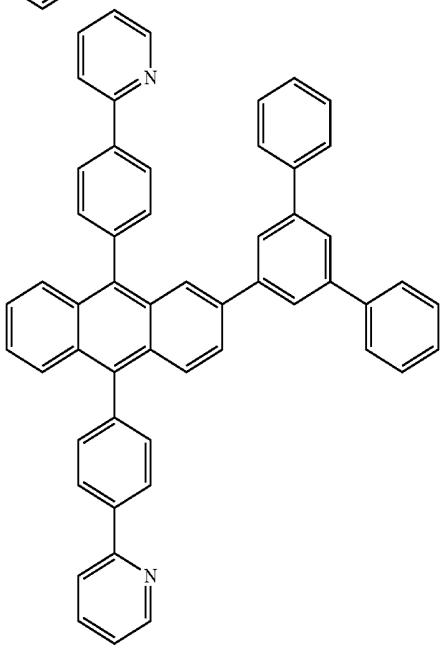

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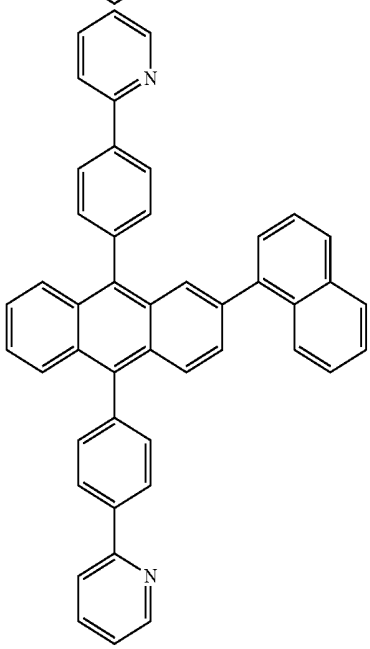

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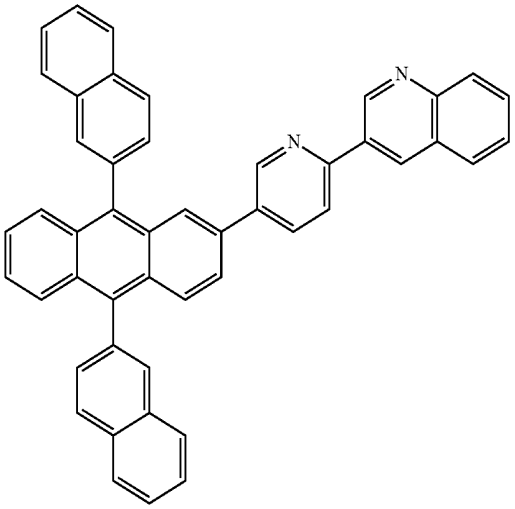
ET11



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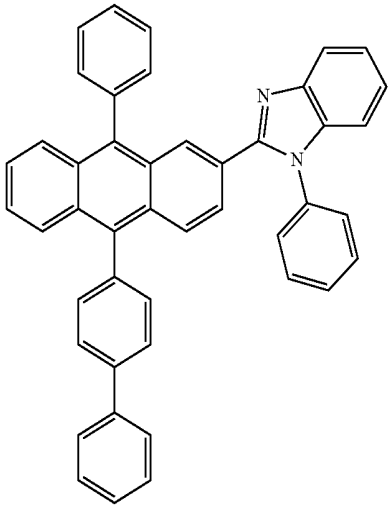
ET14



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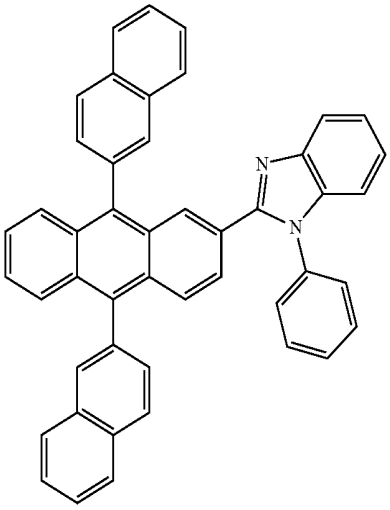

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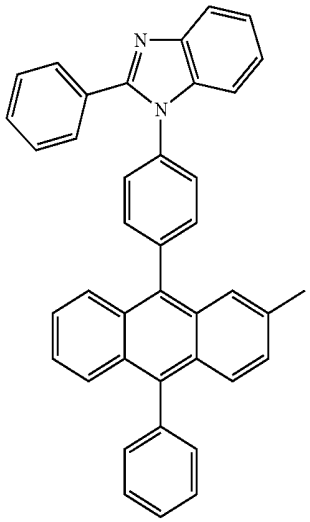

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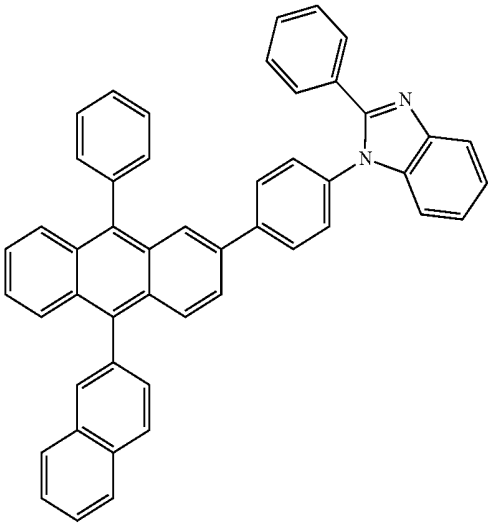
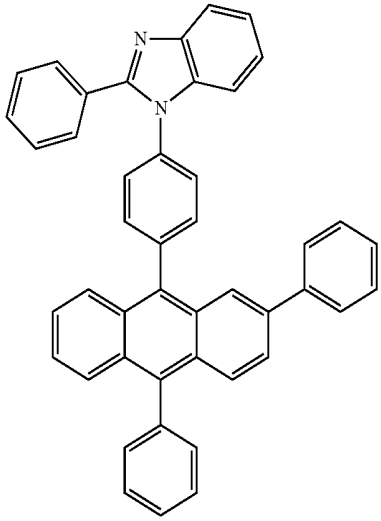


ET16



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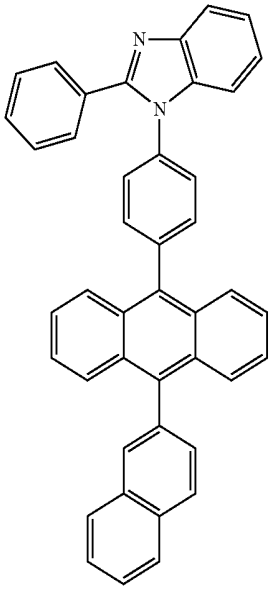
ET17



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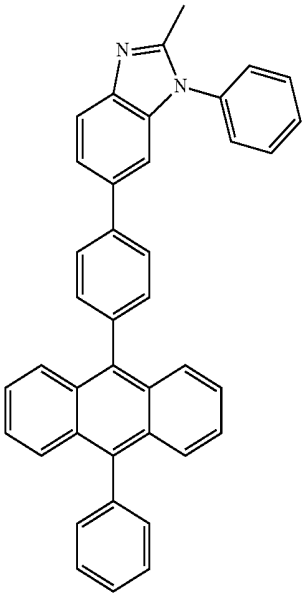
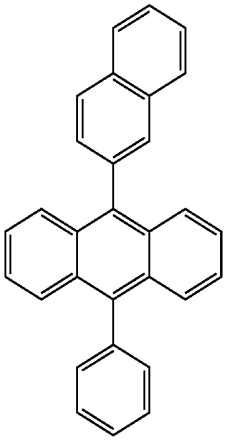


ET19



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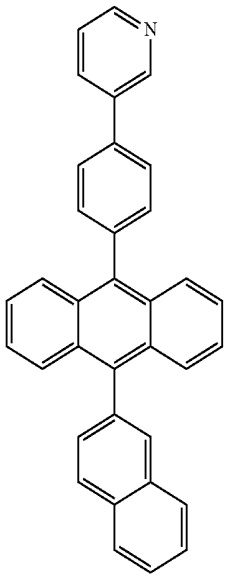
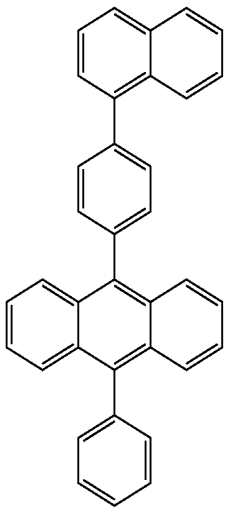
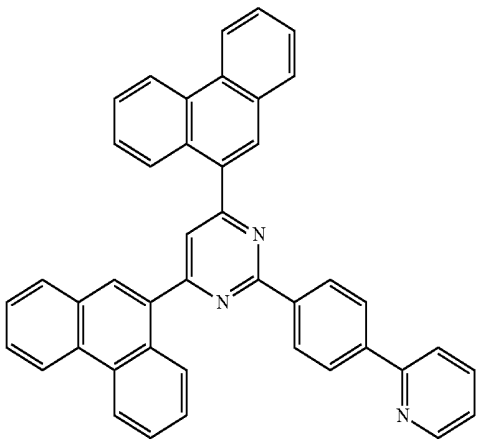
ET20



ET21



ET22



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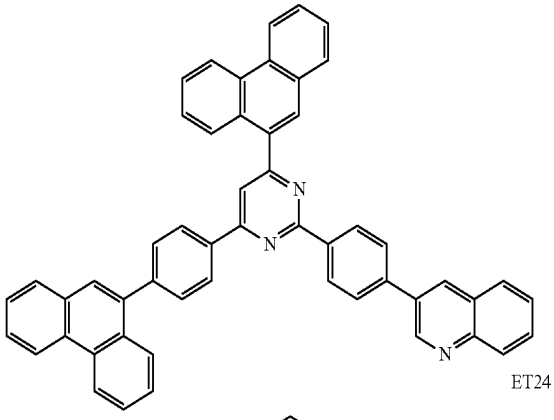
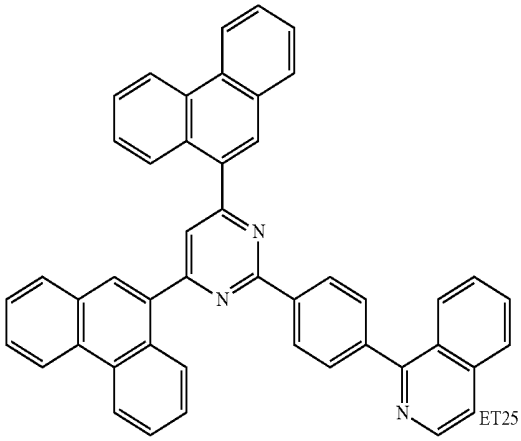
ET23



ET24



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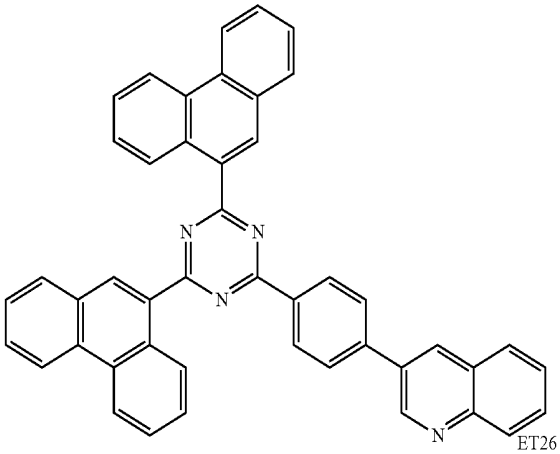

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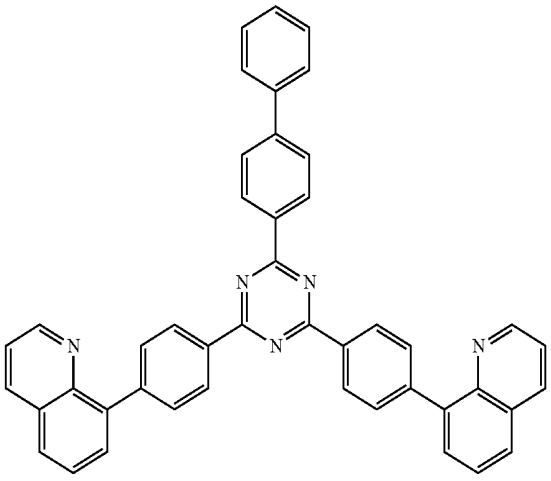

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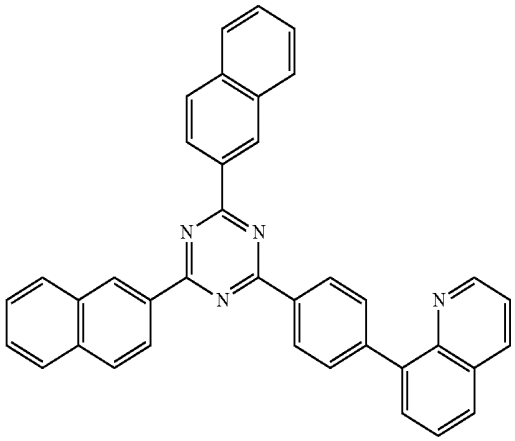

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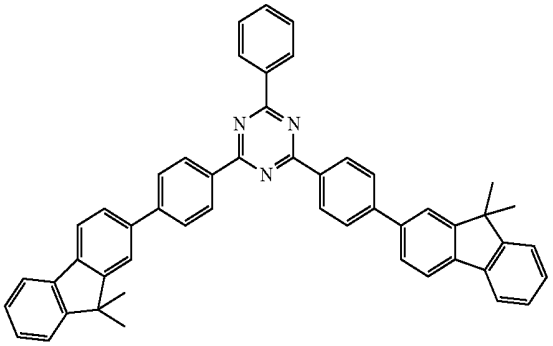

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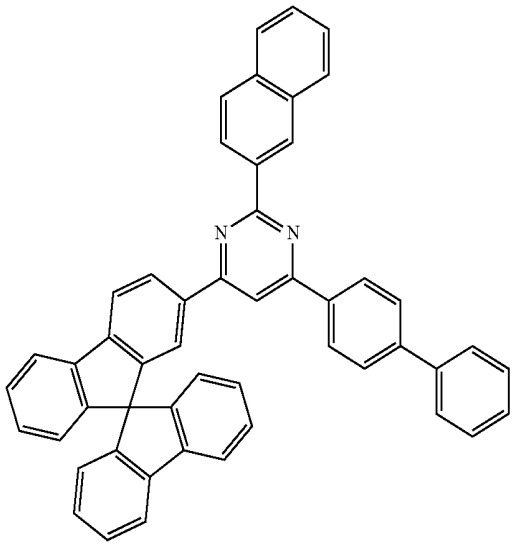

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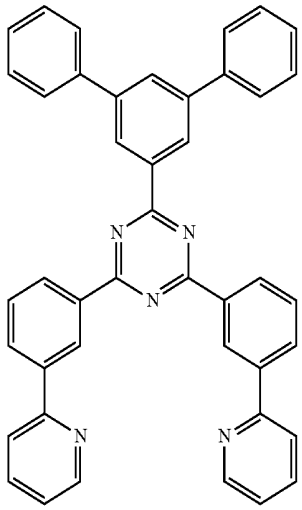
ET30



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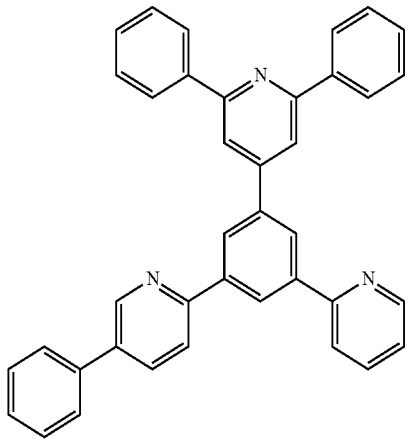

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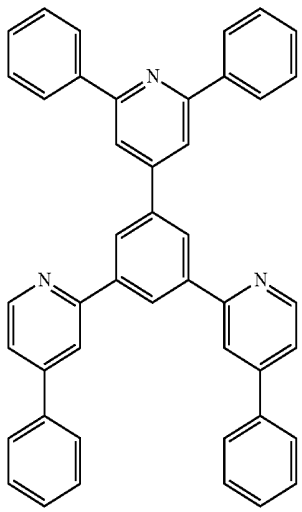

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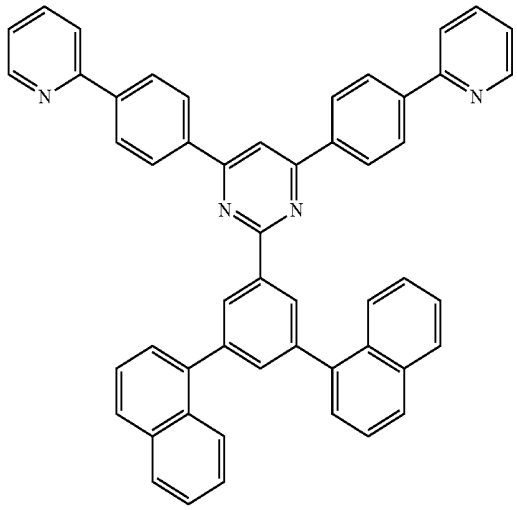
ET33



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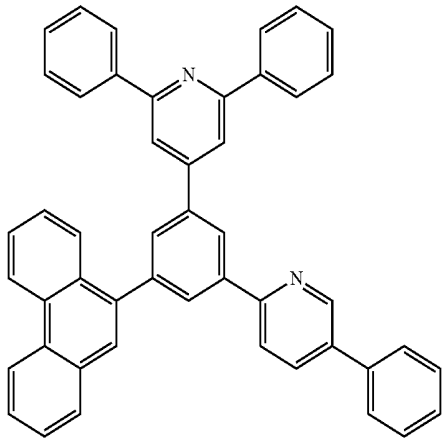
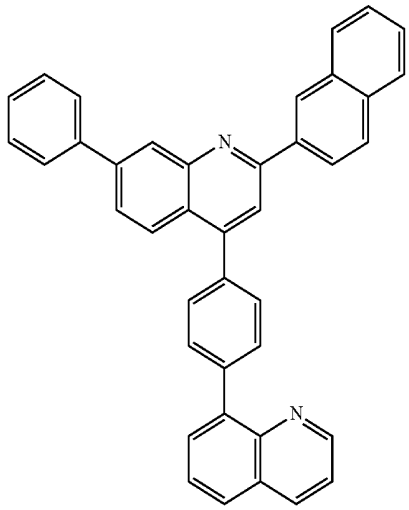


ET35



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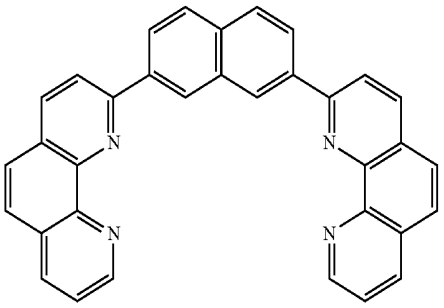
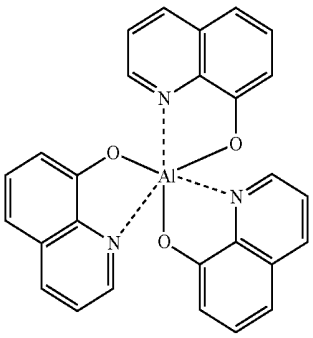
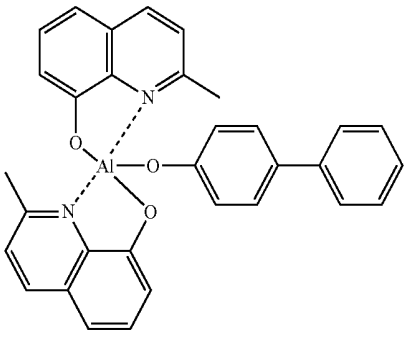
ET36



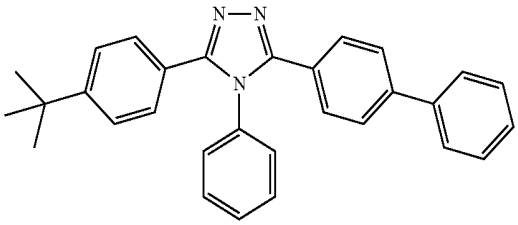
According to an exemplary embodiment of the present invention, the electron transport region may include at least one selected from 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP), 4,7-diphenyl-1,10-phenanthroline (Bphen), Alq_3, BAlq, 3-(biphenyl-4-yl)-5-(4-tert-butylphenyl)-4-phenyl-4H-1,2,4-triazole (TAZ), or NTAZ.



Alq_3



BAl_q



TAZ

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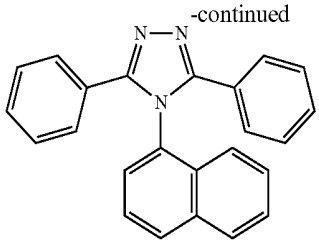


NTAZ

A thickness of the buffer layer, the hole blocking layer, and the electron controlling 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 these ranges, the electron-blocking layer may have relatively high electron blocking characteristics or electron control characteristics without a substantial increase in driving voltage.

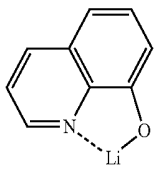
A thickness of the electron transport layer may be in a range of from about 100 Å to about 1,000 Å, for example, from about 150 Å to about 500 Å. When the thickness of the electron transport layer is within the range described above, the electron transport layer may have satisfactory electron transport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

The electron transport region, for example, the electron transport layer in the electron transport region, may include a material including metal.

The material including metal may include at least one of 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) ion, or a caesium (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, an 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 hydroxy quinoline, a hydroxy isoquinoline, a hydroxy benzoquinoline, a hydroxy acridine, a hydroxy phenanthridine, a hydroxy phenylan oxazole, a hydroxy phenylthiazole, a hydroxy diphenylan oxadiazole, a hydroxy diphenylthiadiazol, a hydroxy phenylpyridine, a hydroxy phenylbenzimidazole, a hydroxy phenylbenzothiazole, a bipyridine, a phenanthroline, or a cyclopentadiene; however, exemplary embodiments of the present invention are not limited thereto.

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

ET-D1



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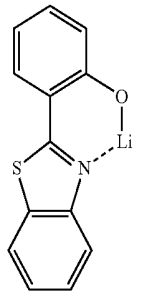
ET-D2



The electron transport region may include an electron injection layer. The electron injection layer may be configured to facilitate injection of electrons from the second electrode **190**. The electron injection layer may be in direct contact with the second electrode **190**.

The electron injection layer may have a single-layered structure including a single layer including a single material. The electron injection layer may have a single-layered structure including a single layer including a plurality of different materials. The electron injection layer may have a multi-layered structure having a plurality of layers including a plurality of different materials.

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

The alkali metal may be selected from Li, Na, K, Rb, or Cs. According to an exemplary embodiment of the present invention, the alkali metal may be Li, Na, or Cs. According to one or more exemplary embodiments of the present invention, the alkali metal may be Li or Cs; however, exemplary embodiments of the present invention are not limited thereto.

The alkaline earth metal may be selected from Mg, Ca, Sr, or Ba.

The rare-earth metal may be selected from Sc, Y, Ce, Yb, Gd, or Tb.

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

The alkali metal compound may be selected from alkali metal oxides, such as Li_2O, Cs_2O, or K_2O, and alkali metal halides, such as LiF, NaF, CsF, KF, LiI, NaI, CsI, KI, or RbI. According to an exemplary embodiment of the present invention, the alkali metal compound may be selected from LiF, Li_2O, NaF, LiI, NaI, CsI, or KI; however, exemplary embodiments of the present invention are not limited thereto.

The alkaline earth-metal compound may be selected from alkaline earth-metal compounds, such as BaO, SrO, CaO, $Ba_xSr_{1-x}O$ ($0<x<1$), or $Ba_xCa_{1-x}O$ ($0<x<1$). According to an exemplary embodiment of the present invention, the alkaline earth-metal compound may be selected from BaO, SrO, or CaO; however, exemplary embodiments of the present invention are not limited thereto.

The rare-earth metal compound may be selected from YbF3, ScF_3, ScO_3, Y_2O_3, Ce_2O_3, GdF_3, or TbF_3. According to an exemplary embodiment of the present invention, the rare-earth metal compound may be selected from YbF_3, ScF_3, TbF_3, YbI_3, ScI_3, or TbI_3; however, exemplary embodiments of the present invention are not limited thereto.

The alkali metal complex, the alkaline earth-metal complex, and the rare-earth metal complex may include an ion of an alkali metal, an alkaline earth-metal, or a rare-earth metal as described above. A ligand coordinated with a metal ion of the alkali metal complex, the alkaline earth-metal complex, and the rare-earth metal complex may each independently be selected from hydroxy quinoline, hydroxy isoquinoline, hydroxy benzoquinoline, hydroxy acridine, hydroxy phenanthridine, hydroxy phenylan oxazole, hydroxy phenylthiazole, hydroxy diphenylan oxadiazole, hydroxy diphenylthiadiazol, hydroxy phenylpyridine, hydroxy phenylbenzimidazole, hydroxy phenylbenzothiazole, bipyridine, phenanthroline, or cyclopentadiene; however, exemplary embodiments of the present invention are not limited thereto.

The electron injection layer may include an alkali metal, an alkaline earth metal, a rare-earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare-earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare-earth metal complex, or any combinations thereof, as described above. In one or more embodiments, the electron injection layer may further include an organic material. When the electron injection layer further includes an organic material, an alkali metal, an alkaline earth metal, a rare-earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare-earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare-earth metal complex, or any combinations thereof and may be substantially homogeneously or non-homogeneously dispersed in a matrix including the organic material.

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

The second electrode **190** may be disposed on the organic layer **150** having such a structure. The second electrode **190** may be a cathode. The cathode may be an electron injection electrode. Accordingly, the second electrode **190** may include a metal, an alloy, an electrically conductive compound, or a combination thereof, which may have a relatively low work function.

The second electrode **190** may include at least one of lithium (Li), silver (Si), magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), magnesium-silver (Mg—Ag), indium tin oxide (ITO), or indium zinc oxide (IZO); however, exemplary embodiments of the present invention are not limited thereto. The second electrode **190** may be a transmissive electrode, a semi-transmissive electrode, or a reflective electrode.

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.

FIG. **2** is a schematic cross-sectional diagram illustrating an organic light-emitting device according to an exemplary embodiment of the present invention. Referring to FIG. **2**, an organic light-emitting device **20** may include 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 according to an exemplary embodiment of the present invention. Referring to FIG. **3**, an organic light-emitting device **30** may include 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 according to an exemplary embodiment of the present invention. Referring to FIG. **4**, an organic light-emitting device **40** may include 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.

In the organic layer **150** of each of the organic light-emitting devices **20** and **40**, light generated by an 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 or a transmissive electrode. In the organic layer **150** of each of the organic light-emitting devices **30** and **40**, light generated by an 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.

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

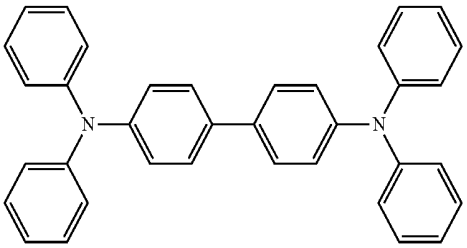
The first capping layer **210** and the second capping layer **220** may each independently be an organic capping layer including an organic material, an inorganic capping layer including an inorganic material, or a composite capping layer including an organic material and an inorganic material.

At least one of the first capping layer **210** and the second capping layer **220** may include at least one material selected from carbocyclic compounds, heterocyclic compounds, amine-based compounds, porphyrine derivatives, phthalocyanine derivatives, naphthalocyanine derivatives, alkali metal complexes, or alkaline earth-based complexes. 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, or I. According to an exemplary embodiment of the present invention, at least one of the first capping layer **210** and the second capping layer **220** may include an amine-based compound.

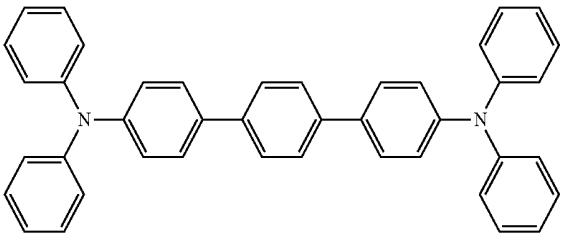
According to an exemplary embodiment of the present invention, at least one of the first capping layer **210** and the second capping layer **220** may include the compound represented by Formula 201 or the compound represented by Formula 202.

According to an exemplary embodiment of the present invention, 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; however, exemplary embodiments of the present invention are not limited thereto.

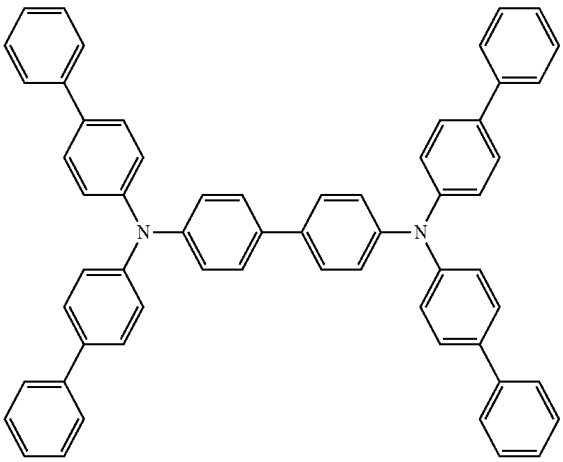
CP1



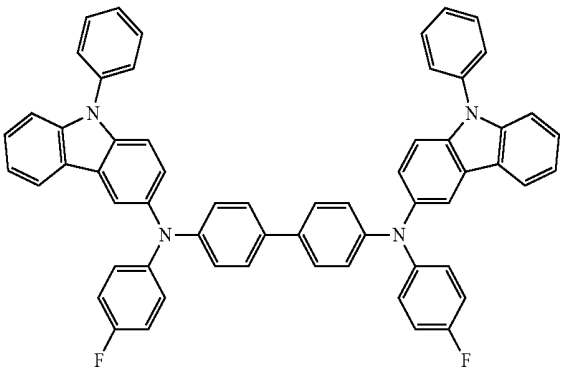
CP2



CP3



CP4



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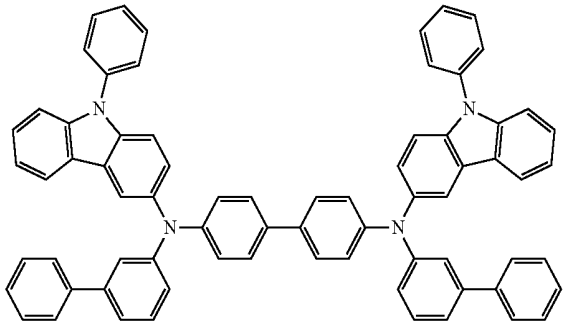
CP5



The organic light-emitting device according to some exemplary embodiments of the present invention has been described in connection with FIGS. **1-4**. However, exemplary embodiments of the present invention are not limited thereto.

Layers included in the hole transport region, the emission layer, and the electron transport region may be formed by, for example, vacuum deposition, spin coating, casting, langmuir-blodgett (LB) deposition, ink-jet printing, laser-printing, or laser-induced thermal imaging.

When the respective layers of the hole transport region, the emission layer, and the respective layers of the electron transport region are formed by deposition, the deposition may be performed at a deposition temperature of from about 100° C. to about 500° C., at a vacuum degree of 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 by taking into account a compound for forming a layer to be deposited, and the structure of a layer to be formed.

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

The term "C_1-C_{60} 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 may 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 "C_1-C_{60} alkylene group" as used herein refers to a divalent group having the same structure as the C_1-C_{60} alkyl group.

The term "C_2-C_{60} 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 C_2-C_{60} alkyl group, and non-limiting examples thereof may include an ethenyl group, a propenyl group, and a butenyl group. The term "C_2-C_{60} alkenylene group" as used herein refers to a divalent group having the same structure as the C_2-C_{60} alkenyl group.

The term "C_2-C_{60} 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 C_2-C_{60} alkyl group, and non-limiting examples thereof may include an ethynyl group and a propynyl group. The term "C_2-C_{60} alkynylene group" as used herein refers to a divalent group having the same structure as the C_2-C_{60} alkynyl group.

The term "C_1-C_{60} alkoxy group" as used herein refers to a monovalent group represented by —OA_{101}, in which A_{101} is the C_1-C_{60} alkyl group), and non-limiting examples thereof may include a methoxy group, an ethoxy group, and an isopropyloxy group.

The term "C_3-C_{10} cycloalkyl group" as used herein refers to a monovalent saturated hydrocarbon monocyclic group having 3 to 10 carbon atoms, and non-limiting examples thereof may include a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. The term "C_3-C_{10} cycloalkylene group" as used herein refers to a divalent group having the same structure as the C_3-C_{10} cycloalkyl group.

The term "C_{10}-C_{10} 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 may include a 1,2,3,4-oxatriazolidinyl group, a tetrahydrofuranyl group, and a tetrahydrothiophenyl group. The term "C_1-C_{10} heterocycloalkylene group" as used herein refers to a divalent group having the same structure as the C_1-C_{10} heterocycloalkyl group.

The term "C_3-C_{10} 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 does not have aromaticity, and non-limiting examples thereof may include a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. The term "C_3-C_{10} cycloalkenylene group" as used herein refers to a divalent group having the same structure as the C_3-C_{10} cycloalkenyl group.

The term "C_1-C_{10} 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 thereof may include a 4,5-dihydro-1,2,3,4-oxatriazolyl group, a 2,3-dihydrofuranyl group and a 2,3-dihydrothiophenyl group. The term "C_1-C_{10} heterocycloalkenylene group" as used herein refers to a divalent group having the same structure as the C_1-C_{10} heterocycloalkenyl group.

The term "C_6-C_{60} aryl group" used herein refers to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms, and the term "C_6-C_{60} arylene group" used herein refers to a divalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms. Non-limiting examples of the C_6-C_{60} aryl group may include a phenyl group, a naphthyl group, an anthracenyl group, a phenanthrenyl group, a pyrenyl group, and a chrysenyl group. When the C_6-C_{60} aryl group and the C_6-C_{60} arylene group each include two or more rings, the rings may be chemically bonded to each other.

The term "C_1-C_{60} 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 "C_1-C_{60} 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 C_1-C_{60} 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 C_1-C_{60} heteroaryl group and the C_1-C_{60} heteroarylene group each include two or more rings, the rings may be chemically bonded to each other.

The term "C_6-C_{60} aryloxy group" as used herein refers to —OA_{102}, in which A_{102} is the C_6-C_{60} aryl group. The term "C_6-C_{60} arylthio group" as used herein indicates —SA_{103}, in which A_{103} is the C_6-C_{60} aryl group.

The term "monovalent non-aromatic condensed polycyclic group" as used herein refers to a monovalent group, for example, having 8 to 60 carbon atoms. The monovalent group has two or more rings condensed with each other. Additionally, only carbon atoms are used as a ring-forming atom. The entire molecular structure has non-aromaticity. An example of the monovalent non-aromatic condensed polycyclic group is a fluorenyl group. The term "divalent non-aromatic condensed polycyclic group" as used herein refers to a divalent group having the same structure as the monovalent non-aromatic condensed polycyclic group.

The term "monovalent non-aromatic condensed heteropolycyclic group" as used herein refers to a monovalent group, for example, having 1 to 60 carbon atoms. The monovalent group has two or more rings condensed with each other. The monovalent group has at least one heteroatom selected from N, O, Si, P, and S. Additionally, atoms other than carbon atoms are used as a ring-forming atom. The entire molecular structure has non-aromaticity. An example of the monovalent non-aromatic condensed heteropolycyclic group is a carbazolyl group. The term "divalent non-aromatic condensed heteropolycyclic group" as used herein, refers to a divalent group having the same structure as the monovalent non-aromatic condensed heteropolycyclic group.

The term "C_5-C_{60} 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 C_5-C_{60} carbocyclic group may be an aromatic carbocyclic group or a non-aromatic carbocyclic group. The C_5-C_{60} carbocyclic group may be a ring, such as a benzene, a monovalent group, such as a phenyl group, or a divalent group, such as a phenylene group. In one or more exemplary embodiments of the present invention, depending on the number of substituents connected to the C_5-C_{60} carbocyclic group, the C_5-C_{60} carbocyclic group may be a trivalent group or a quadrivalent group.

The term "C_1-C_{60} heterocyclic group" used herein refers to a group having the same structure as the C_1-C_{60} carbocyclic group, except that as a ring-forming atom, at least one heteroatom selected from N, O, Si, P, and S is used in addition to carbon. The number of carbon atoms may be in a range of 1 to 60.

At least one of substituents of the substituted C_5-C_{60} carbocyclic group, the substituted C_1-C_{60} heterocyclic group, the substituted C_3-C_{10} cycloalkylene group, the substituted C_1-C_{10} heterocycloalkylene group, the substituted C_3-C_{10} cycloalkenylene group, the substituted C_1-C_{10} heterocycloalkenylene group, the substituted C_6-C_{60} arylene group, the substituted C_1-C_{60} heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, the substituted divalent non-aromatic condensed heteropolycyclic group, the substituted C_1-C_{60} alkyl group, the substituted C_2-C_{60} alkenyl group, the substituted C_2-C_{60} alkynyl group, the substituted C_1-C_{60} alkoxy group, the substituted C_3-C_{10} cycloalkyl group, the substituted C_1-C_{10} heterocycloalkyl group, the substituted C_3-C_{10} cycloalkenyl group, the substituted C_1-C_{10} heterocycloalkenyl group, the substituted C_6-C_{60} aryl group, the substituted C_6-C_{60} aryloxy group, the substituted C_6-C_{60} arylthio group, the substituted C_1-C_{60} heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, or the substituted monovalent non-aromatic condensed heteropolycyclic group, used herein, may be selected from:

deuterium(-D), —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, or a C_1-C_{60} alkoxy group;

a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —$Si(Q_{11})(Q_{12})(Q_{13})$, —$N(Q_{11})(Q_{12})$, —$B(Q_{11})(Q_{12})$, —$C(=O)(Q_{11})$, —$S(=O)_2(Q_{11})$, or —$P(=O)(Q_{11})(Q_{12})$;

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

a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic 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 C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —$Si(Q_{21})(Q_{22})(Q_{23})$, —$N(Q_{21})(Q_{22})$, —$B(Q_{21})(Q_{22})$, —$C(=O)(Q_{21})$, —$S(=O)_2(Q_{21})$, or —$P(=O)(Q_{21})(Q_{22})$; or

—$Si(Q_{31})(Q_{32})(Q_{33})$, —$N(Q_{31})(Q_{32})$, —$B(Q_{31})(Q_{32})$, —$C(=O)(Q_{31})$, —$S(=O)_2(Q_{31})$, and —$P(=O)(Q_{31})(Q_{32})$.

Q_1 to Q_6, Q_{11} to Q_{13}, Q_{21} to Q_{23} and Q_{31} to Q_{33} may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, or a terphenyl group.

The term "Ph" used herein refers to a phenyl group; the term "Me", used herein, refers to a methyl group; the term "Et", used herein, refers to an ethyl group; the terms "ter-Bu" or "But", used herein, refers to a tert-butyl group; and the term "OMe" used herein refers to a methoxy group.

The term "biphenyl group" used therein refers to "a phenyl group substituted with a phenyl group." As an

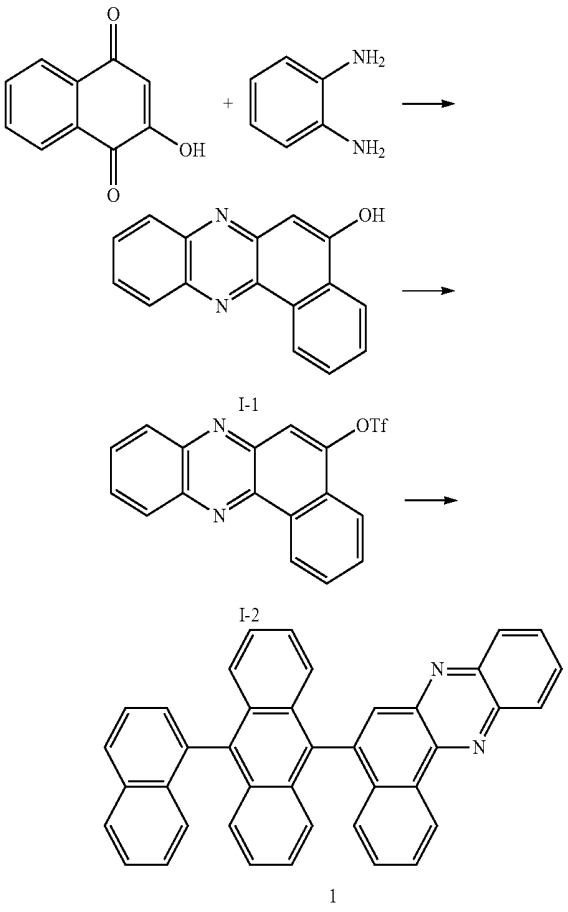
example, a "biphenyl group" is a substituted phenyl group having a C_6-C_{60} aryl group as a substituent.

The term "terphenyl group" 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 C_6-C_{60} aryl group substituted with a C_6-C_{60} aryl group as a substituent. * and *' used herein, unless defined otherwise, each refer to a binding site to a neighboring atom in a corresponding formula.

A compound according to one or more exemplary embodiments of the present invention and an organic light-emitting device according to one or more exemplary embodiments of the present invention will be described in more detail below with reference to Synthesis Examples and Examples. However, exemplary embodiments of the present invention are not limited to the Examples described herein. 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



Synthesis of Intermediate I-1

5.22 g (30.0 mmol) of 2-hydroxy-1,4-naphthoquinone and 3.24 g (30.0 mmol) of 1,2-diaminobenzene were dissolved in 80 mL of H_2O and were then stirred at a temperature of 50° C. for 12 hours. The obtained reacting solution was cooled to room temperature. Then, an organic layer was extracted three times by using 60 mL of water and 60 mL of ethyl etherdiethyl ether. The organic layer was dried by using magnesium sulfate and the solvent was evaporated. The obtained residue was separated and purified by silica gel column chromatography, thereby completing the preparation of 3.69 g (50%) of Intermediate I-1. Intermediate I-1 was confirmed through LC-MS.

$C_{16}H_{10}N_2O$: M+1 246.1

Synthesis of Intermediate I-2

3.69 g (15.0 mmol) of Intermediate I-1 was dissolved in 50 mL of toluene and mL of 30% potassium phosphate, and 5.07 g (18.0 mmol) of trifluoromethanesulfonic acid anhydride was slowly added dropwise at a temperature of 0° C. Then, the obtained reacting solution was heated to room temperature and was then stirred for 3 hours. Then, 30 mL of water was added thereto and an organic layer was extracted three times by using 30 mL of ethyl ether. The organic layer was dried by using magnesium sulfate and the solvent was evaporated. The obtained residue was separated and purified by silica gel column chromatography, thereby completing the preparation of 4.65 g (82%) of Intermediate I-2. Intermediate I-2 was confirmed through LC-MS.

$C_{20}H_{15}N$: M+1 378.3

Synthesis of Compound 1

3.78 g (10.0 mmol) of Intermediate I-2, 4.30 g (10 mmol) of 4,4,5,5-tetramethyl-2-(10-(naphthalen-1-yl)anthracen-9-yl)-1,3,2-dioxaborolane, 0.578 g (0.50 mmol) of $Pd(PPh_3)_4$, and 4.15 g (30.0 mmol) of K_2CO_3 were dissolved in 60 mL of a mixed solution of THF and H_2O (a volume ratio of 2:1) and were then stirred at a temperature of, 80° C. for 16 hours. The obtained reacting solution was cooled to room temperature. Then, 40 mL of water was added thereto, and an organic layer was extracted three times by using 50 mL of ethyl ether. The organic layer was dried by using magnesium sulfate and the solvent was evaporated. The obtained residue was separated and purified by silica gel column chromatography, thereby completing the preparation of 3.73 g (70%) of Compound 1. Compound 1 was confirmed through MS/FAB and ^1H NMR. $C_{40}H_{24}N_2$ cal. 532.19. found 532.20.

Synthesis Example 2: Synthesis of Compound 3

3.65 g (72%) of Compound 3 was prepared in substantially the same manner as in Synthesis of Compound 1, except that 4-(10-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)anthracen-9-yl)benzonitrile was used instead of 4,4,5,5-tetramethyl-2-(10-(naphthalen-1-yl)anthracen-9-yl)-1,3,2-dioxaborolane in Synthesis of Compound 1. Compound 3 was confirmed through MS/FAB and ^1H NMR. $C_{37}H_{21}N_3$ cal. 507.17. found 507.16.

Synthesis Example 3: Synthesis of Compound 7

3.76 g (67%) of Compound 7 was prepared in substantially the same manner as in Synthesis of Compound 1, except that 6-(10-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)anthracen-9-yl)-2,4'-bipyridine was used instead of 4,4,5,5-tetramethyl-2-(10-(naphthalen-1-yl)anthracen-9-yl)-1,3,2-dioxaborolane in Synthesis of Compound 1. Compound 7 was confirmed through MS/FAB and ^1H NMR. $C_{40}H_{24}N_4$ cal. 560.20. found 560.21.

Synthesis Example 4: Synthesis of Compound 9

2.60 g (50%) of Compound 9 was prepared in substantially the same manner as in Synthesis of Compound 1, except that 2,6-difluoro-3-(10-(4,4,5,5-tetramethyl-1,3,2-di-

oxaborolan-2-yl)anthracen-9-yl)pyridine was used instead of 4,4,5,5-tetramethyl-2-(10-(naphthalen-1-yl)anthracen-9-yl)-1,3,2-dioxaborolane in Synthesis of Compound 1. Compound 9 was confirmed through MS/FAB and ^{1}H NMR. $C_{35}H_{19}F_2N_3$ cal. 519.15. found 519.16.

Synthesis Example 5: Synthesis of Compound 14

4.23 g (63%) of Compound 14 was prepared in substantially the same manner as in Synthesis of Compound 1, except that 9-phenyl-6-(10-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)anthracen-9-yl)-9H-carbazole-2-carbonitrile was used instead of 4,4,5,5-tetramethyl-2-(10-(naphthalen-1-yl)anthracen-9-yl)-1,3,2-dioxaborolane in Synthesis of Compound 1. Compound 14 was confirmed through MS/FAB and ^{1}H NMR. $C_{49}H_{28}N_4$ cal. 672.23. found 672.22.

Synthesis Example 6: Synthesis of Compound 20

3.72 g (71%) of Compound 20 was prepared in substantially the same manner as in Synthesis of Compound 1, except that 9,9-dimethyl-7-(3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)phenyl)-9H-fluorene-2-carbonitrile was used instead of 4,4,5,5-tetramethyl-2-(10-(naphthalen-1-yl) anthracen-9-yl)-1,3,2-dioxaborolane in Synthesis of Compound 1. Compound 20 was confirmed through MS/FAB and ^{1}H NMR. $C_{38}H_{25}N_3$ cal. 523.20. found 523.21.

Synthesis Example 7: Synthesis of Compound 21

3.78 g (66%) of Compound 21 was prepared in substantially the same manner as in Synthesis of Compound 1, except that 9-phenyl-6-(4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)phenyl)-9H-carbazole-2-carbonitrile was used instead of 4,4,5,5-tetramethyl-2-(10-(naphthalen-1-yl)anthracen-9-yl)-1,3,2-dioxaborolane in Synthesis of Compound 1. Compound 21 was confirmed through MS/FAB and ^{1}H NMR. $C_{41}H_{24}N_4$ cal. 572.20. found 572.19.

Synthesis Example 8: Synthesis of Compound 28

3.00 g (60%) of Compound 28 was prepared in substantially the same manner as in Synthesis of Compound 1, except that 3-(9,9-dimethyl-7-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-9H-fluoren-2-yl)pyridine was used instead of 4,4,5,5-tetramethyl-2-(10-(naphthalen-1-yl)anthracen-9-yl)-1,3,2-dioxaborolane in Synthesis of Compound 1. Compound 28 was confirmed through MS/FAB and ^{1}H NMR. $C_{36}H_{25}N_3$ cal. 499.20. found 499.21.

Synthesis Example 9: Synthesis of Compound 41

3.92 g (73%) of Compound 41 was prepared in substantially the same manner as in Synthesis of Compound 1, except that 2,4-diphenyl-6-(3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)phenyl)-1,3,5-triazine was used instead of 4,4,5,5-tetramethyl-2-(10-(naphthalen-1-yl)anthracen-9-yl)-1,3,2-dioxaborolane in Synthesis of Compound 1. Compound 41 was confirmed through MS/FAB and ^{1}H NMR. $C_{37}H_{23}N_5$ cal. 537.20. found 537.22.

Synthesis Example 10: Synthesis of Compound 43

3.40 g (67%) of Compound 43 was prepared in substantially the same manner as in Synthesis of Compound 1, except that diphenyl(3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)phenyl)phosphine oxide was used instead of 4,4,5,5-tetramethyl-2-(10-(naphthalen-1-yl)anthracen-9-yl)-1,3,2-dioxaborolane in Synthesis of Compound 1. Compound 43 was confirmed through MS/FAB and ^{1}H NMR. $C_{34}H_{23}N_2OP$ cal. 506.15. found 506.16.

^{1}H NMR and MS/FAB of synthesized Compounds are shown in Table 1 below. Methods of synthesizing compounds other than Compounds shown in Table 1 are recognizable by one of ordinary skill in the art by referring to the synthesis path and source materials described above.

TABLE 1

Compound	^{1}H NMR ($CDCl_3$, 400 MHz)	MS/FAB found	MS/FAB calc.
1	δ = 9.31 (d, 1H), 8.75 (s, 1H), 8.30 (d, 1H), 8.25 (d, 1H), 7.88-7.80 (m, 8H), 7.73-7.69 (m, 3H), 7.53 (d, 1H), 7.45 (d, 1H), 7.37-7.30 (m, 6H), 7.20-7.17 (m, 1H)	532.20	532.19
3	δ = 9.30 (d, 1H), 8.76 (s, 1H), 8.28 (d, 1H), 8.22 (d, 1H), 7.90-7.66 (m, 12H), 7.37-7.30 (m, 5H)	507.16	507.17
7	δ = 9.31 (d, 1H), 8.75 (s, 1H), 8.65-8.63 (m, 2H), 8.29 (d, 1H), 8.25 (d, 1H), 8.03-8.01 (m, 2H), 7.91-7.68 (m, 9H), 7.54 (d, 2H), 7.42-7.32 (m, 3H), 7.13-7.10 (m, 2H)	560.21	560.20
9	δ = 9.29 (d, 1H), 8.92 (d, 2H), 8.75 (s, 1H), 8.66 (d, 1H), 8.30 (d, 1H), 8.25 (d, 1H), 8.11 (d, 2H), 7.88-7.80 (m, 3H), 7.73-7.68 (m, 1H), 7.63-7.59 (m, 2H), 7.36-7.32 (m, 3H), 7.15-7.12 (m, 1H)	519.16	519.15
14	δ = 9.32 (d, 1H), 8.77 (s, 1H), 8.30 (d, 1H), 8.26-8.24 (m, 2H), 8.09 (d, 1H), 8.03, 7.88-7.79 (m, 9H), 7.73-7.68 (m, 1H), 7.63-7.48 (m, 6H), 7.40-7.28 (m, 6H)	672.22	672.23
20	δ = 9.10 (d, 1H), 8.53 (s, 1H), 8.30 (d, 1H), 8.23 (d, 1H), 8.20 (d, 1H), 8.13 (d, 1H), 7.80-7.79 (m, 4H), 7.73-7.65 (m, 2H), 7.57 (d, 1H), 7.50 (d, 1H), 7.45-7.43 (m, 2H), 7.38-7.36 (m, 1H), 7.31-7.24 (m, 2H), 1.59 (s, 6H)	523.21	523.20
21	δ = 9.03 (d, 1H), 8.39 (s, 1H), 8.30 (d, 1H), 8.26 (d, 1H), 8.18-8.03 (m, 6H), 7.85-7.69 (m, 6H), 7.63-7.48 (m, 6H), 7.32-7.28 (m, 1H), 7.22-7.19 (m, 1H)	572.19	572.20
28	δ = 9.10 (d, 1H), 8.93 (d, 1H), 8.65 (d, 1H), 8.31 (d, 1H), 8.23 (d, 2H), 8.10-8.03 (m, 3H), 7.99 (d, 1H), 7.84-7.70 (m, 6H), 7.56 (d, 1H), 7.42-7.39 (d, 1H), 7.28-7.25 (d, 1H), 1.61 (s, 6H)	499.21	499.20

TABLE 1-continued

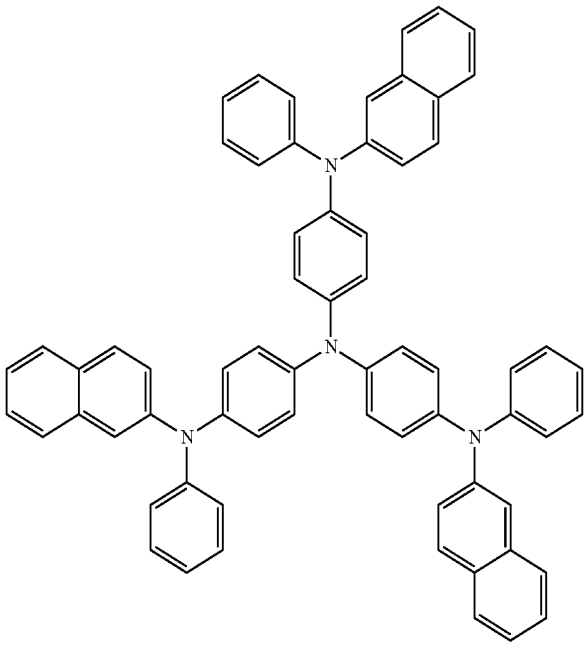
Compound	^{1}H NMR ($CDCl_3$, 400 MHz)	MS/FAB found	MS/FAB calc.
41	δ = 9.09 (d, 1H), 8.81-8.78 (m, 4H), 8.68-8.66 (m, 1H), 8.63-8.61 (m, 1H), 8.46 (s, 1H), 8.30 (d, 1H), 8.25 (d, 1H), 8.20 (d, 1H), 8.07 (d, 1H), 7.84-7.78 (m, 2H), 7.73-7.59 (m, 6H), 7.42-7.38 (m, 2H), 7.28-7.25 (m, 1H)	537.22	537.20
43	δ = 9.10 (d, 1H), 8.55 (s, 1H), 8.29 (d, 1H), 8.21 (d, 1H), 8.13 (d, 1H), 8.02 (d, 1H), 7.90-7.77 (m, 3H), 7..73-7.63 (m, 5H), 7.60-7.48 (m, 4H), 7.43-7.39 (m, 4H), 7.28-7.25 (m, 1H)	506.16	506.15

Example 1

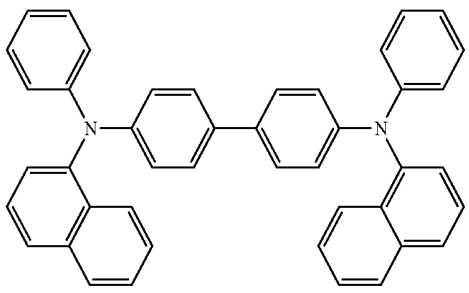
An anode was prepared by cutting an ITO glass substrate, on which an ITO layer was deposited to a thickness of 15 Ω/cm^2 (1,200 Å), to a size of 50 mm×50 mm×0.7 mm, ultrasonically cleaning the ITO glass substrate (anode) using isopropyl alcohol and pure water each for 5 minutes, and exposing the ITO glass substrate (anode) to UV irradiation for 30 minutes and ozone to clean the ITO glass substrate.

Then, the glass substrate (anode) was loaded into a vacuum deposition apparatus.

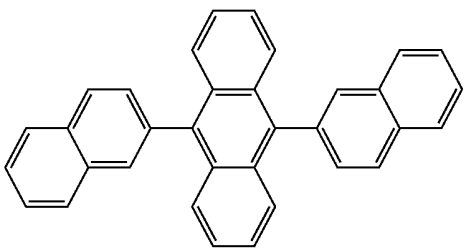
2-TNATA was vacuum-deposited on the ITO glass substrate (anode) to form a hole injection layer having a thickness of 600 Å. 4,4'-bis[N-(1-naphthyl)-N-phenylamino]bisphenyl (NPB) was vacuum-deposited on the hole injection layer to form a hole transport layer having a thickness of about 300 Å.



2-TNATA

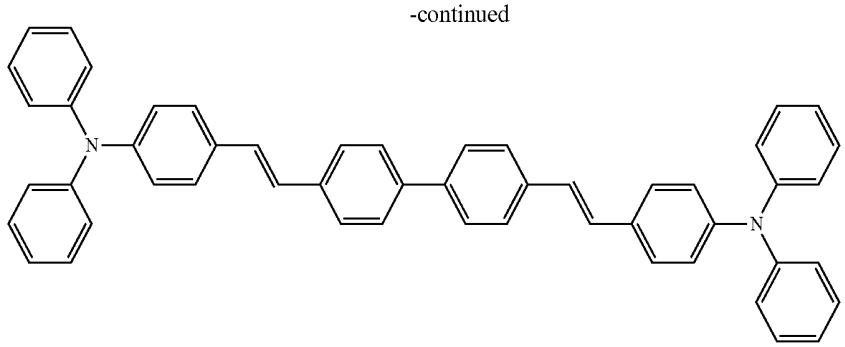


NPB



ADN

-continued



DPAVBi

9,10-di-naphthalene-2-yl-anthracene (ADN) (blue fluorescent host) and 4,4'-bis[2-(4-(N,N-diphenylamino)phenyl) vinyl]biphenyl (DPAVBi) (blue fluorescent dopant) were co-deposited on the hole transport layer at a weight ratio of 98:2 to form an emission layer having a thickness of about 300 Å.

Compound 1 was deposited on the emission layer to form an electron transport layer having a thickness of about 300 Å. 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 an LiF/Al cathode having a thickness of about 3,000 Å. Thus, an organic light-emitting device was formed.

Examples 2 to 10 and Comparative Examples 1 and 2

Organic light-emitting devices of Examples 2 to 10 and Comparative Examples 1 and 2 were manufactured in substantially the same manner as in Example 1, except that Compounds shown in Table 2 were used instead of Compound 1 in forming an electron transport layer.

Evaluation Example 1

The driving voltage, current density, luminance, efficiency, emission color, and half lifespan of the organic light-emitting devices manufactured in Examples 1 to 10 and Comparative Examples 1 and 2 were evaluated using Keithley SMU 236 and PR650 luminance meters. Results thereof are shown in Table 2. The half lifespan was obtained by measuring a period of time that had lapsed until the luminance (@100 mA/cm^2) was reduced to 50% of the initial luminance after driving the organic light-emitting device.

TABLE 2

	Material	Driving Voltage Voltage (V)	Current density (mA/cm^2)	Luminance (cd/m^2)	Efficiency (cd/A)	Emission color	Half lifespan (hr @ 100 mA/cm^2)
Example 1	Compound 1	3.20	50	3,760	7.52	Blue	625 hr
Example 2	Compound 3	3.32	50	3,850	7.70	Blue	650 hr
Example 3	Compound 7	3.35	50	3,795	7.59	Blue	662 hr
Example 4	Compound 9	3.26	50	3,960	7.92	Blue	756 hr
Example 5	Compound 14	3.37	50	3,985	7.97	Blue	730 hr
Example 6	Compound 20	3.30	50	3,900	7.80	Blue	775 hr
Example 7	Compound 21	3.42	50	3,920	7.84	Blue	763 hr
Example 8	Compound 28	3.35	50	3,815	7.63	Blue	712 hr
Example 9	Compound 41	3.40	50	3,755	7.51	Blue	607 hr
Example 10	Compound 43	3.67	50	3,530	7.06	Blue	826 hr
Comparative Example 1	Compound 63 Compound 200	4.28	50	3,250	6.50	Blue	485 hr
Comparative Example 2		5.06	50	3,010	6.02	Blue	325 hr

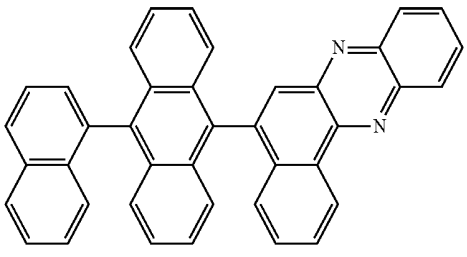


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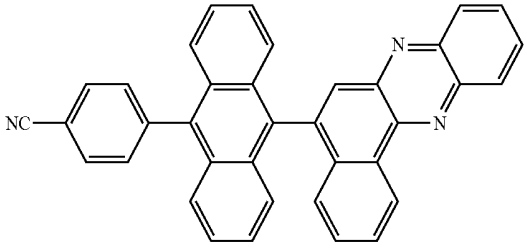
TABLE 2-continued

Material	Driving Voltage Voltage (V)	Current density (mA/cm^2)	Luminance (cd/m^2)	Efficiency (cd/A)	Emission color	Half lifespan (hr @ 100 mA/cm^2)



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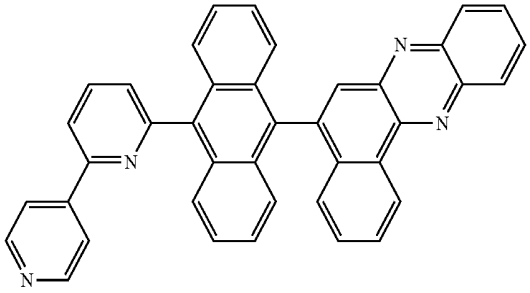

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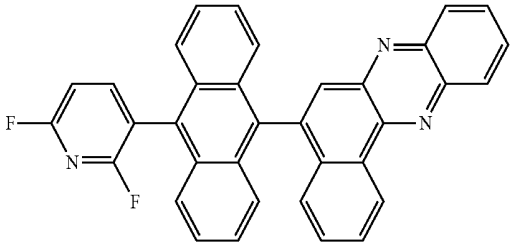

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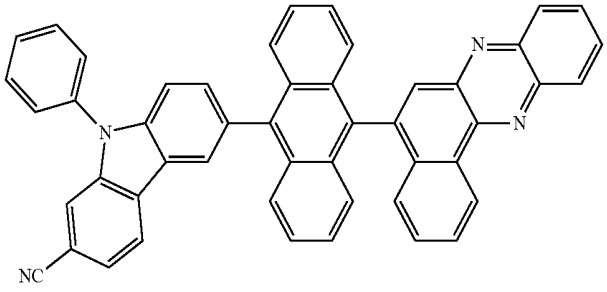

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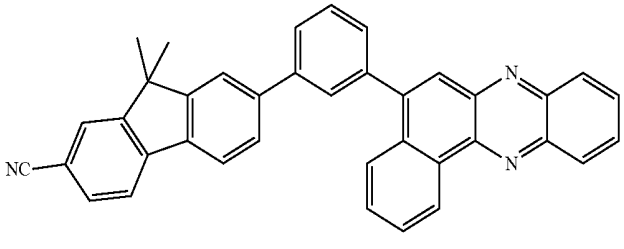

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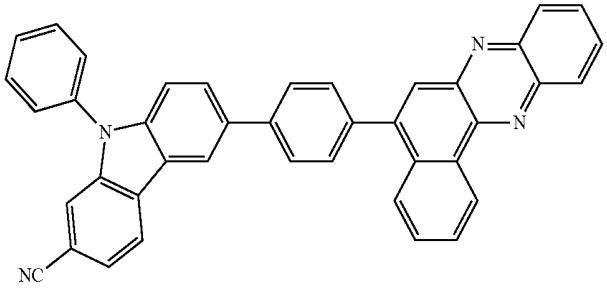
TABLE 2-continued

Material	Driving Voltage Voltage (V)	Current density (mA/cm^2)	Luminance (cd/m^2)	Efficiency (cd/A)	Emission color	Half lifespan (hr @ 100 mA/cm^2)



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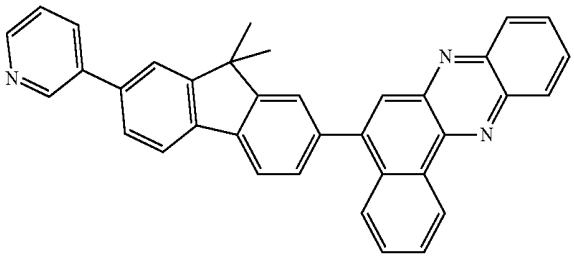

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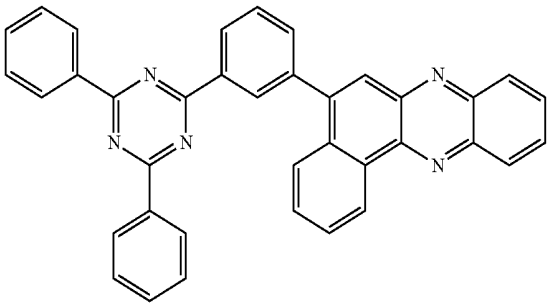

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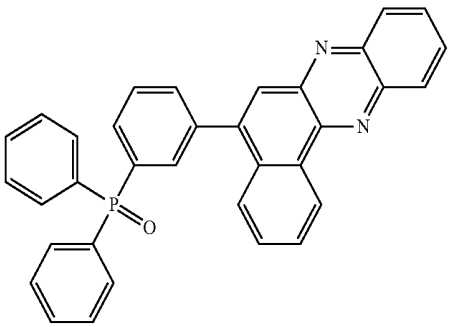

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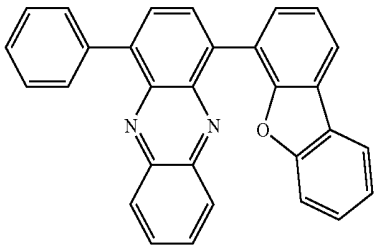

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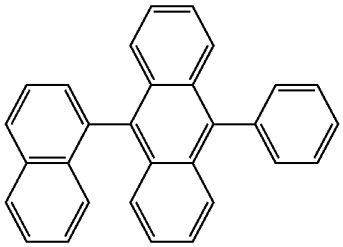
TABLE 2-continued

Material	Driving Voltage Voltage (V)	Current density (mA/cm^2)	Luminance (cd/m^2)	Efficiency (cd/A)	Emission color	Half lifespan (hr @ 100 mA/cm^2)



200

Referring to Table 2, the organic light-emitting devices of Examples 1 to 10 had relatively high driving voltage, efficiency, and lifespan characteristics, compared to those of Comparative Examples 1 and 2.

According to an exemplary embodiment of the present invention, the organic light-emitting device including the condensed cyclic compound may have a relatively low driving voltage, relatively high efficiency, and a relatively long lifespan.

It should be understood that one or more exemplary embodiments of the present invention 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 exemplary embodiments of the present invention.

While one or more exemplary embodiments of the present invention have been described with reference to the figures, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present inventive concept.

What is claimed is:

1. An organic light-emitting device, comprising:

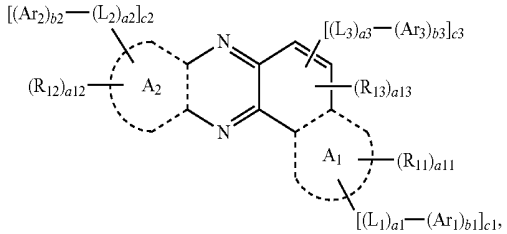
a first electrode;

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 of a condensed cyclic compound represented by Formula 1:

<Formula 1>



wherein A_1 and A_2 in Formula 1 are each independently selected from a benzene group, a naphthalene group, a quinoline group, an isoquinoline group, or a quinazoline group,

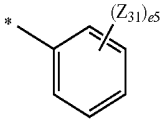
L_1 to L_3 in Formula 1 are each independently selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3-C_{10} cycloalkenylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene 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, a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group, *—P(=O)(Q_4)-*', *—P(=S)(Q_4)-*', *—S(=O)—*', or *—S(=O)$_2$—*',

a1 to a3 in Formula 1 are each independently an integer selected from 0 to 7, wherein when a1 is 2 or greater, at least two L_1(s) are the same or different from each other, when a2 is 2 or greater, at least two L_2(s) are the same or different from each other, and when a3 is 2 or greater, at least two L_3(s) are the same or different from each other,

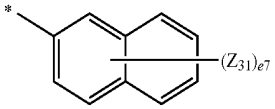
Ar_1 and Ar_2 in Formula 1 are each independently selected from a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —S(=O)$_2$(Q_4), —P(=O)(Q_4)(Q_5), —P(=S)(Q_4)(Q_5), or —S(=O)(Q_4),

Ar_3 in Formula 1 is selected from groups represented by Formulae 3-1 to 3-31:

Formula 3-1



Formula 3-2



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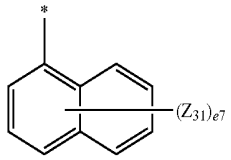
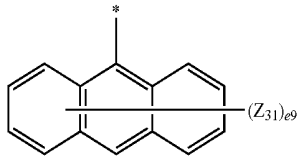


Formula 3-4



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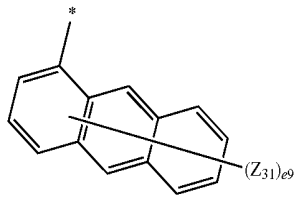
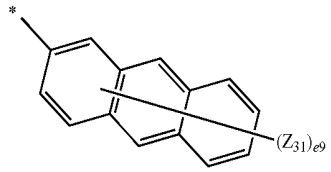


Formula 3-6



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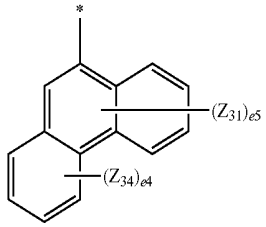
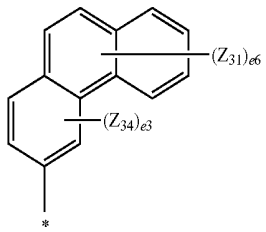
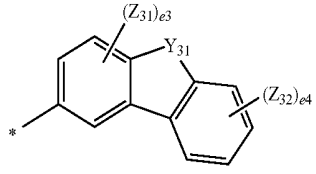


Formula 3-8



Formula 3-9



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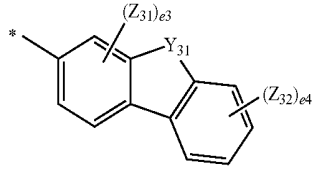

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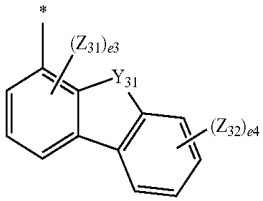

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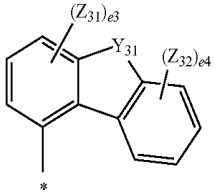

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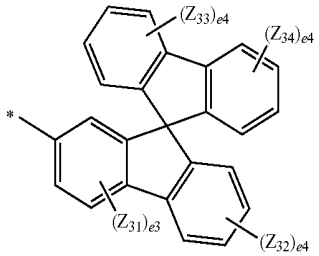

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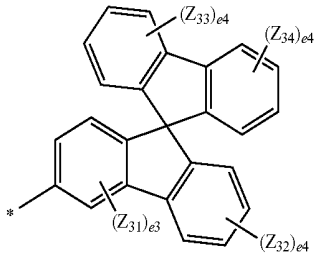

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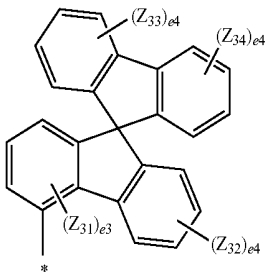

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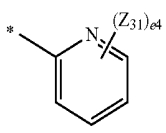

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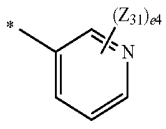

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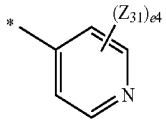

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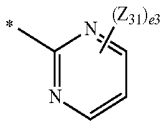

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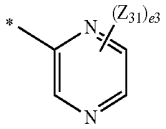

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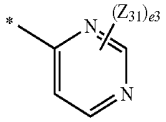

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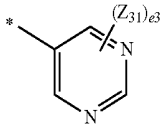

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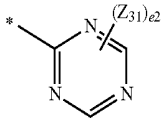

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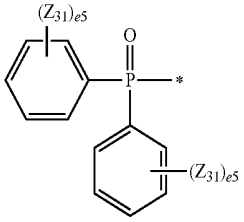

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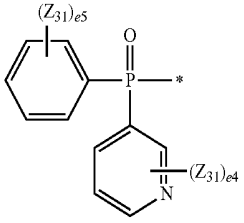

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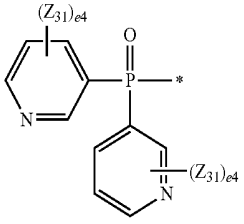

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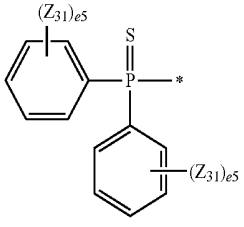

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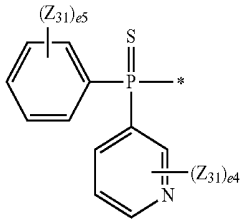

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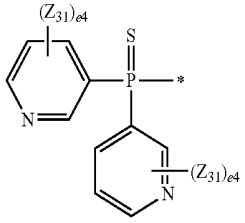

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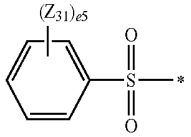
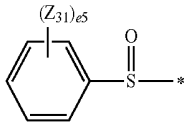


Formula 3-31



Y_{31} is selected from O, S, $C(Z_{35})(Z_{36})$, $N(Z_{37})$, or $Si(Z_{38})(Z_{39})$,

Z_{31} to Z_{39} 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} 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, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-benzofluorene-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an indolyl group, an isoindolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, an isoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl

group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphthosilolyl group, a thiadiazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafluorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indenocarbazolyl group, or an indolocarbazolyl group,

e2 is an integer selected from 0 or 2,

e3 is an integer selected from 0 to 3,

e4 is an integer selected from 0 to 4,

e5 is an integer selected from 0 to 5,

e6 is an integer selected from 0 to 6,

e7 is an integer selected from 0 to 7, and

e9 is an integer selected from 0 to 9;

b1 to b3 in Formula 1 are each independently an integer selected from 1 to 7, wherein when b1 is two or greater, at least two Ar_1(s) are the same or different from each other, when b2 is two or greater, at least two Ar_2(s) are the same or different from each other, and when b3 is two or greater, at least two Ar_3(s) are the same or different from each other,

c1 and c2 in Formula 1 are each independently an integer selected from 0 to 6, and c3 is an integer selected from 1 to 2,

c1 to c3 satisfy the formula of c1+c2+c3≥1,

provided that, if c3 is 2, *-$(L_3)_{a3}$-$(Ar_3)_{b3}$ is not a phenyl group or a substituted phenyl group,

R_{11} and R_{12}, in Formula 1 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} aryithio 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, —$Si(Q_1)(Q_2)(Q_3)$, or —$S(=O)_2(Q_1)$,

R_{13} in Formula 1 is 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, and a C_1-C_{20} alkoxy group;

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, a nitro group, an amidino group, a hydrazino group, or a hydrazono group;

a cyclopentyl group, a cyclohexyl group, a cyclopentenyl group, a cyclohexenyl group, a biphenyl group, or a terphenyl group; and

a cyclopentyl group, a cyclohexyl group, a cyclopentenyl group, a cyclohexenyl 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 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 cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, or a terphenyl group,

a11 and a12 in Formula 1 are each independently an integer selected from 0 to 6, and a13 is an integer selected from 0 to 2, wherein when a11 is 2 or greater, at least two R_{11}(s) are the same or different from each other, when a12 is 2 or more, at least two R_{12}(s) are the same or different from each other, and when a13 is 2, two of R_{13}(s) are the same or different from each other, and

at least one substituent selected from a substituent(s) of the substituted C_3-C_{10} cycloalkylene group, the substituted C_1-C_{10} heterocycloalkylene group, the substituted C_3-C_{10} cycloalkenylene group, the substituted C_1-C_{10} heterocycloalkenylene group, the substituted C_6-C_{60} arylene group, the substituted C_1-C_{60} heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, the substituted divalent non-aromatic condensed heteropolycyclic group, the substituted C_1-C_{60} alkyl group, the substituted C_2-C_{60} alkenyl group, the substituted C_2-C_{60} alkynyl group, the substituted C_1-C_{60} alkoxy group, the substituted C_3-C_{10} cycloalkyl group, the substituted C_1-C_{10} heterocycloalkyl group, the substituted C_3-C_{10} cycloalkenyl group, the substituted C_1-C_{10} heterocycloalkenyl group, the substituted C_6-C_{60} aryl group, the substituted C_6-C_{60} aryloxy group, the substituted C_6-C_{60} arylthio group, the substituted C_1-C_{60} heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, or the substituted monovalent non-aromatic condensed heteropolycyclic group is selected from:

deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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, or a substituted or unsubstituted C_1-C_{60} alkoxy group;

a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —$Si(Q_{11})(Q_{12})(Q_{13})$, —$N(Q_{11})(Q_{12})$, —$B(Q_{11})(Q_{12})$, —$C(=O)(Q_{11})$, —$S(=O)_2(Q_{11})$, or —$P(=O)(Q_{11})(Q_{12})$;

a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60}

aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, or a monovalent non-aromatic condensed heteropolycyclic group;

a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic 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 C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $—Si(Q_{21})(Q_{22})(Q_{23})$, $—N(Q_{21})(Q_{22})$, $—B(Q_{21})(Q_{22})$, $—C(=O)(Q_{21})$, $—S(=O)_2(Q_{21})$, or $—P(=O)(Q_{21})(Q_{22})$; and

$—Si(Q_{31})(Q_{32})(Q_{33})$, $—N(Q_{31})(Q_{32})$, $—B(Q_{31})(Q_{32})$, $—C(=O)(Q_{31})$, $—S(=O)_2(Q_{31})$, or $—P(=O)(Q_{31})(Q_{32})$,

wherein Q_1 to Q_5, Q_{21} to Q_{23}, and Q_{31} to Q_{33} 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_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, or a terphenyl group, and wherein

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

2. The organic light-emitting device of claim **1**, wherein c1 to c3 in Formula 1 satisfy the formula of c1+c2+c3=1.

3. The organic light-emitting device of claim **1**, wherein in Formula 1, c1 is 0, c2 is 0, and c3 is 1.

4. The organic light-emitting device of claim **1**, wherein A_1 and A_2 in Formula 1 are selected from a benzene group and a naphthalene group.

5. The organic light-emitting device of claim **1**, wherein L_1 to L_3 in Formula 1 are each independently selected from:

a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene 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, a pyridinylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isoxazolylene group, a thiadiazolylene group, an oxadiazolylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, or an azacarbazolylene group;

a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene 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, a pyridinylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isoxazolylene group, a thiadiazolylene group, an oxadiazolylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl

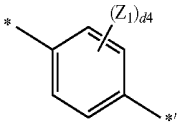
group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl 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, or an azacarbazolyl group; and

—P(=O)(Q_4)-', *—P(=S)(Q_4)-*', *—S(=O)—*', or *—$S(=O)_2$—*',

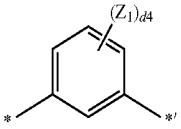
wherein Q_4 is selected from a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group.

6. The organic light-emitting device of claim **1**, wherein L_1 to L_3 in Formula 1 are each independently selected from groups represented by Formulae 2-1 to 2-35:

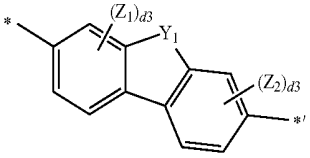
Formula 2-1



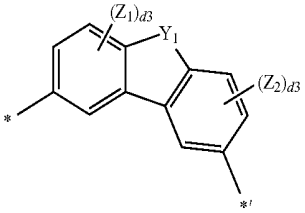
Formula 2-2



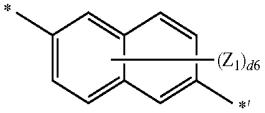
Formula 2-3



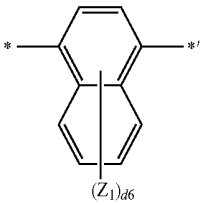
Formula 2-4



Formula 2-5



Formula 2-6



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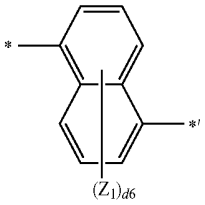
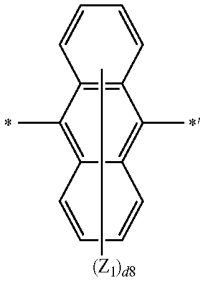
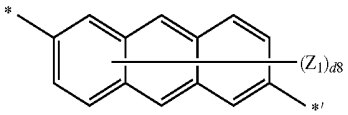
Formula 2-7



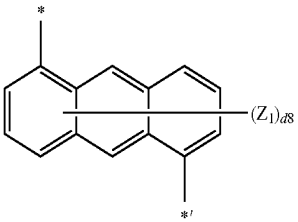
Formula 2-8



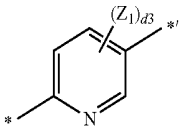
Formula 2-9



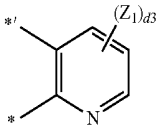
Formula 2-10



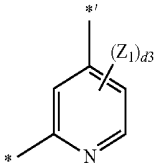
Formula 2-11



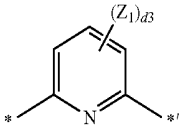
Formula 2-12



Formula 2-13



Formula 2-14



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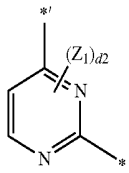
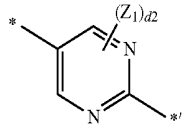
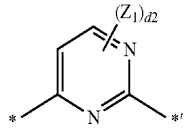
Formula 2-15



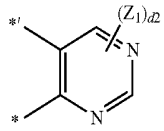
Formula 2-16



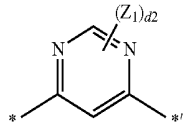
Formula 2-17



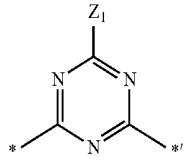
Formula 2-18



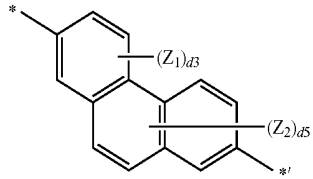
Formula 2-19



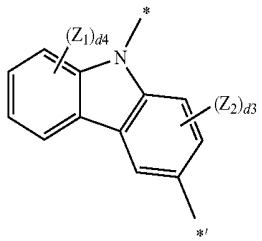
Formula 2-20



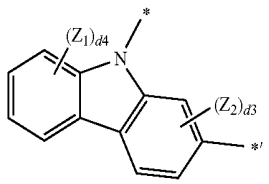
Formula 2-21



Formula 2-22



Formula 2-23



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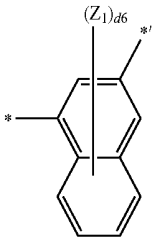
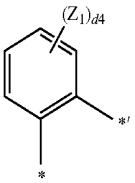
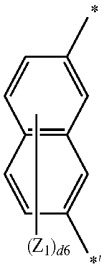
Formula 2-24



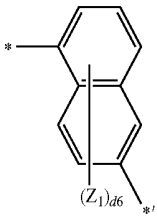
Formula 2-25



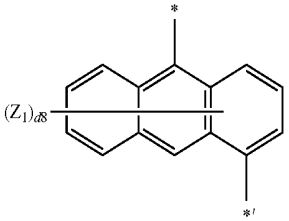
Formula 2-26



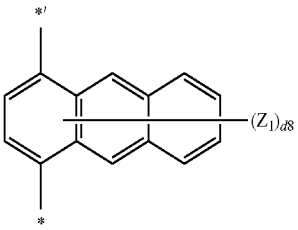
Formula 2-27



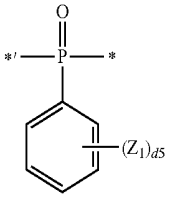
Formula 2-28



Formula 2-29



Formula 2-30



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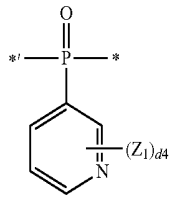
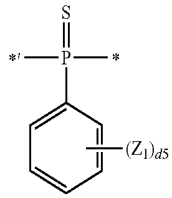
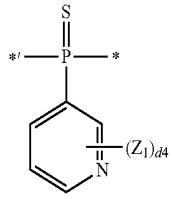
Formula 2-31



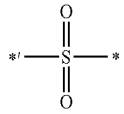
Formula 2-32



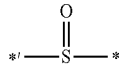
Formula 2-33



Formula 2-34



Formula 2-35



wherein, in Formulae 2-1 to 2-35,

Y_1 is selected from O, S, $C(Z_3)(Z_4)$, $N(Z_5)$, or $Si(Z_6)(Z_7)$,

Z_1 to Z_7 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} 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, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-benzofluorene-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an indolyl group, an isoindolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, an isoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphthosilolyl group, a thiadiazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafluorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indenocarbazolyl group, or an indolocarbazolyl group,

d2 is an integer selected from 0 to 2,

d3 is an integer selected from 0 to 3,

d4 is an integer selected from 0 to 4,

d5 is an integer selected from 0 to 5,

d6 is an integer selected from 0 to 6, and

d8 is an integer selected from 0 to 8.

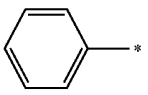
7. The organic light-emitting device of claim **6**, wherein L_1 to L_3 are each independently selected from groups represented by Formulae 2-1 to 2-3, 2-5, 2-8, 2-14, 2-17, 2-20, and 2-30 to 2-35.

8. The organic light-emitting device of claim **1**, wherein a1 to a3 in Formula 1 are each independently an integer selected from 0, 1, or 2.

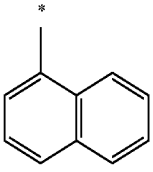
9. The organic light-emitting device of claim **1**, wherein Ar_1 to Ar_3 are each independently selected from groups represented by Formulae 3-1 to 3-4, 3-9 to 3-11, 3-13, 3-16 to 3-19, 3-23, 3-24, 3-26, 3-27, and 3-29 to 3-31.

10. The organic light-emitting device of claim **1**, wherein Ar_1 to Ar_3 in Formula 1 are each independently selected from groups represented by Formulae 4-1 to 4-31:

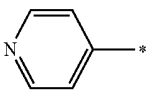
Formula 4-1



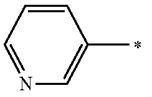
Formula 4-2



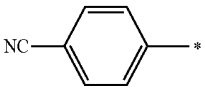
Formula 4-3



Formula 4-4



Formula 4-5



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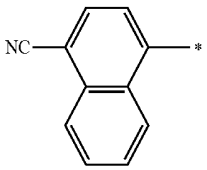
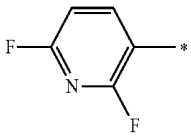
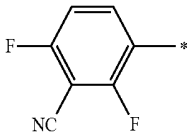
Formula 4-6



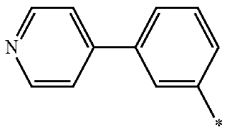
Formula 4-7



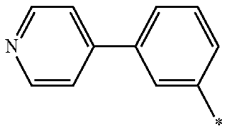
Formula 4-8



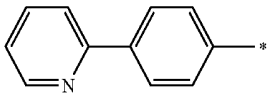
Formula 4-9



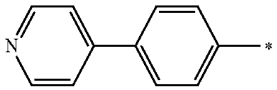
Formula 4-10



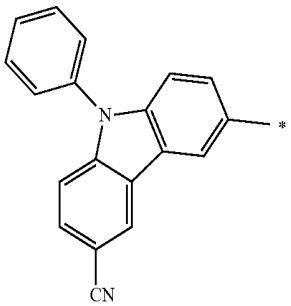
Formula 4-11



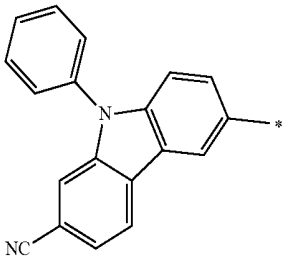
Formula 4-12



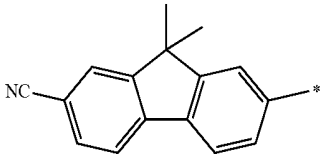
Formula 4-13



Formula 4-14



Formula 4-15



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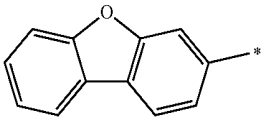
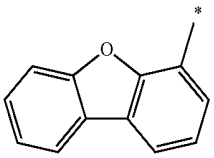
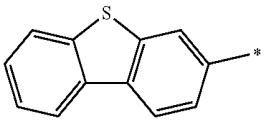
Formula 4-16



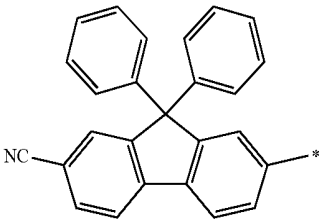
Formula 4-17



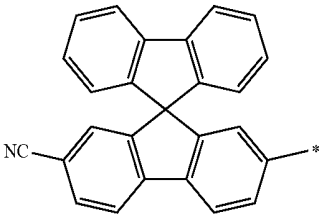
Formula 4-18



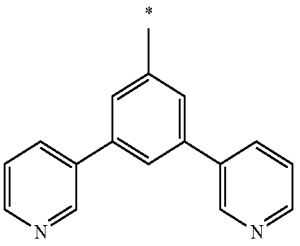
Formula 4-19



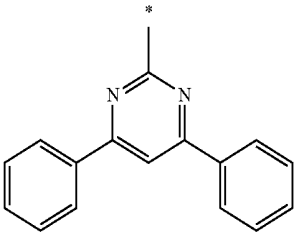
Formula 4-20



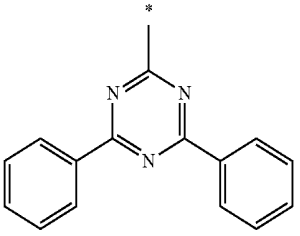
Formula 4-21



Formula 4-22



Formula 4-23



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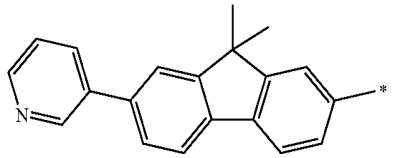
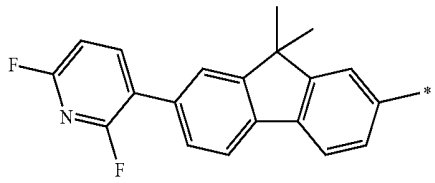
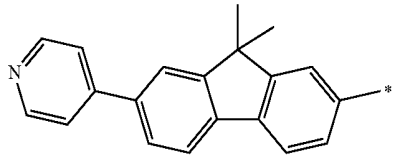
Formula 4-24



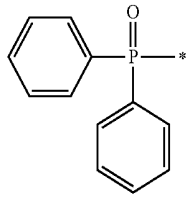
Formula 4-25



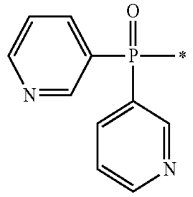
Formula 4-26



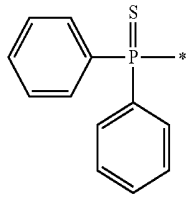
Formula 4-27



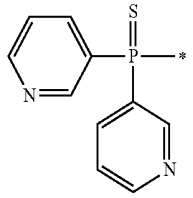
Formula 4-28



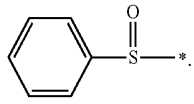
Formula 4-29



Formula 4-30



Formula 4-31

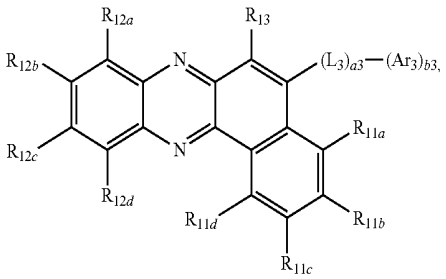


11. The organic light-emitting device of claim **1**, wherein b1 to b3 in Formula 1 are each independently an integer selected from 1 to 3.

12. The organic light-emitting device of claim **1**, wherein a11 to a13 in Formula 1 are each independently an integer selected from 0 to 2.

13. The organic light-emitting device of claim **1**, wherein the compound represented by Formula 1 is represented by Formula 1-1:

<Formula 1-1>

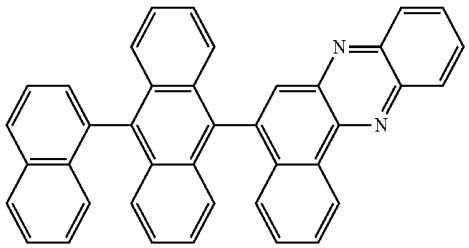


wherein L_3, a3, Ar_3, b3, and R_{13} in Formula 1-1 are the same as described in claim **1**, and

R_{11a} to R_{11d} and R_{12a} to R_{12d} in Formula 1-1 are the same as R_{11} and R_{12} in claim **1**.

14. A condensed cyclic compound selected from Compounds 1 to 60:

1



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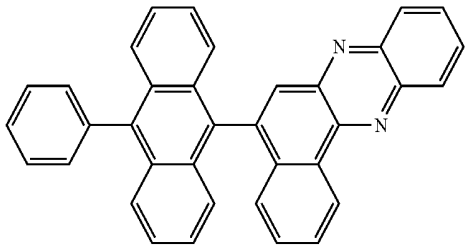

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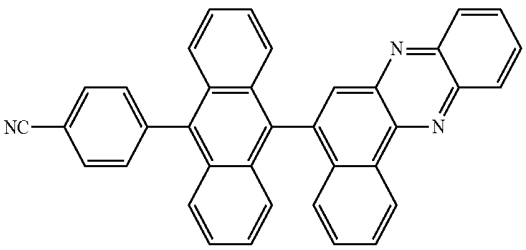

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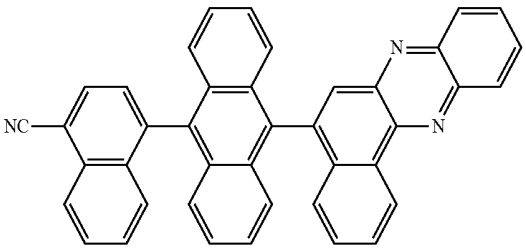

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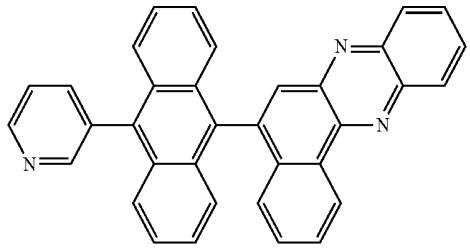

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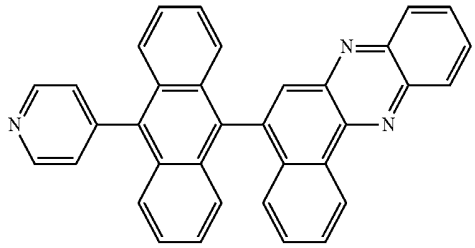

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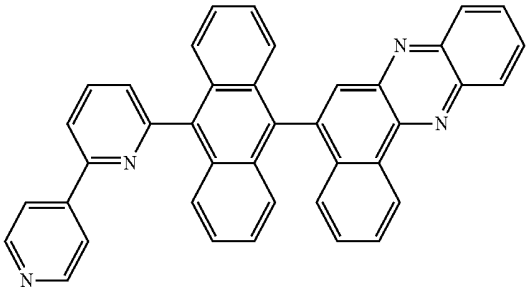

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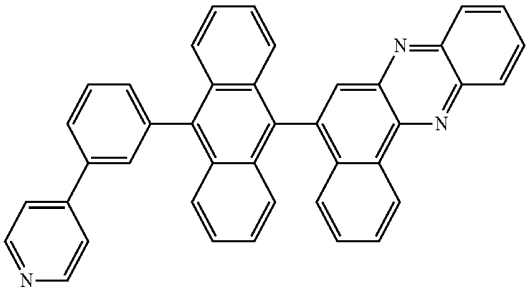

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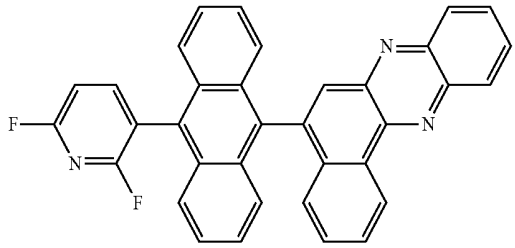

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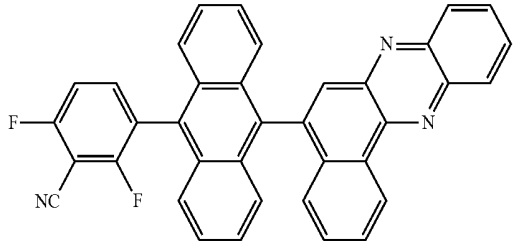

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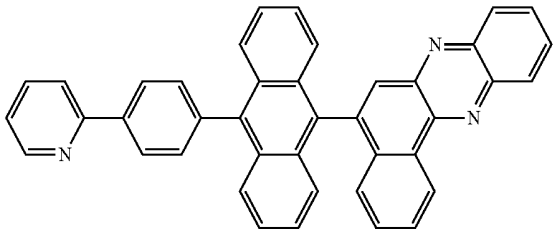

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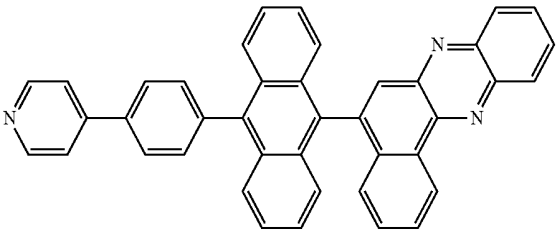

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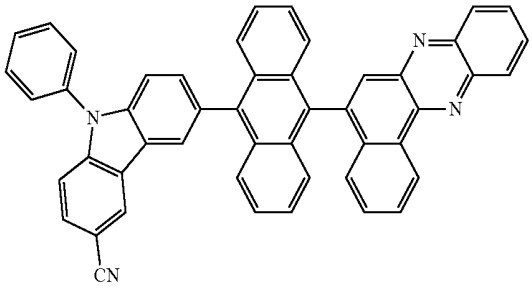

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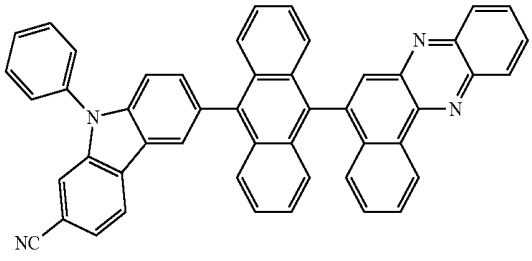

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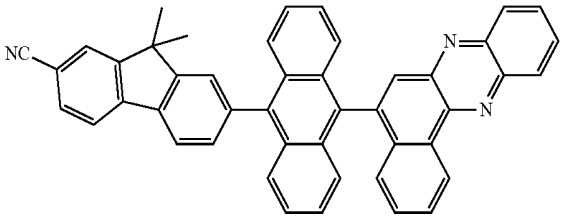

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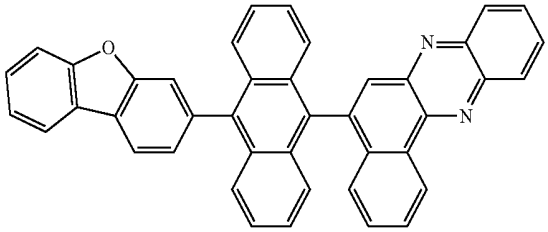

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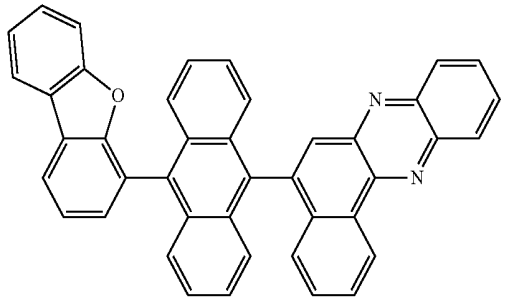

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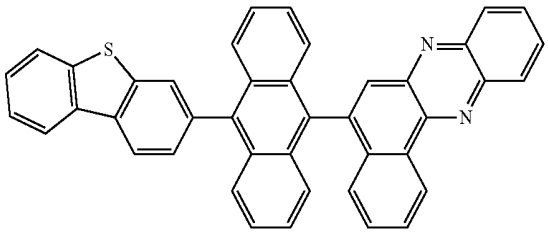

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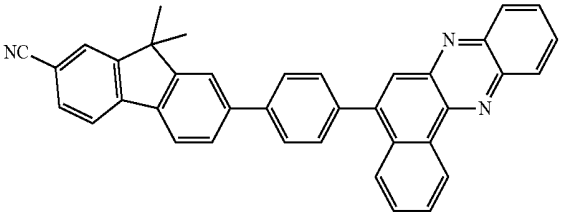

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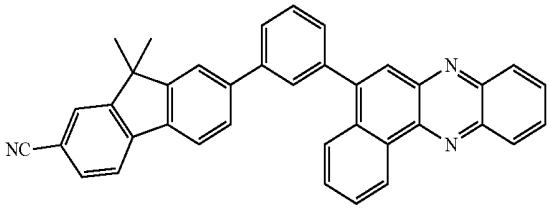

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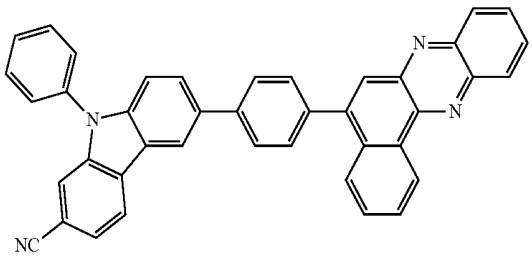

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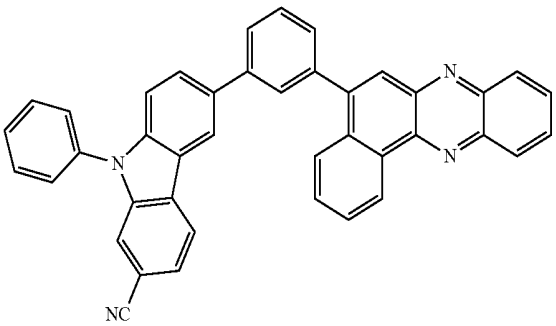

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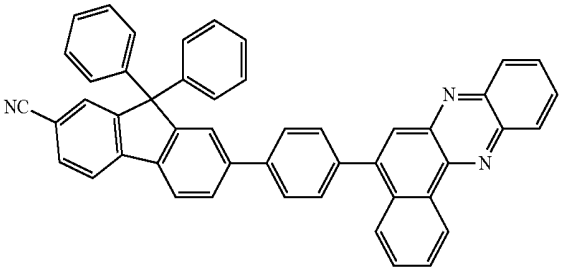

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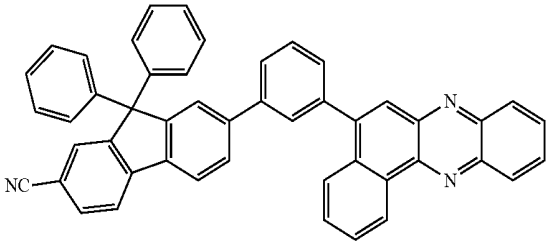

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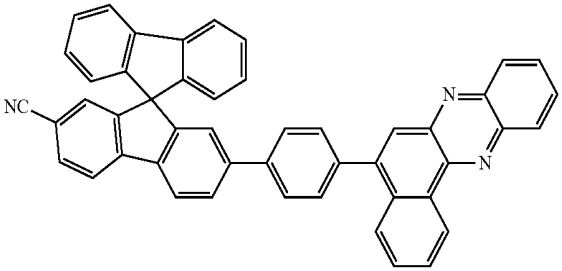

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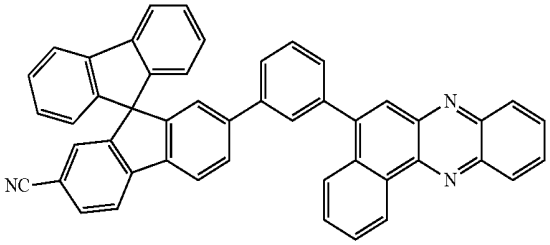

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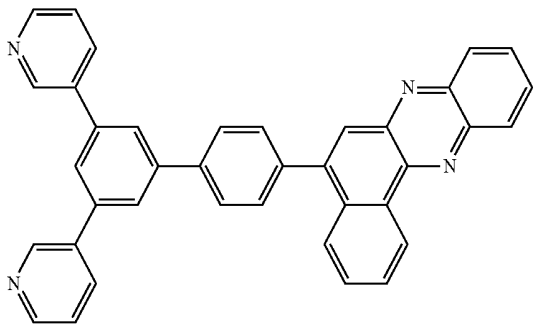

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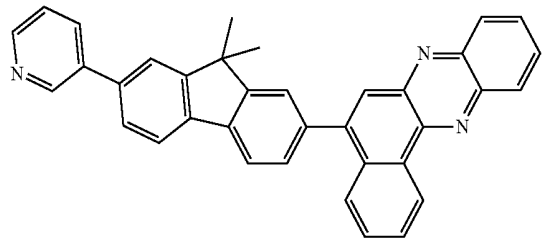

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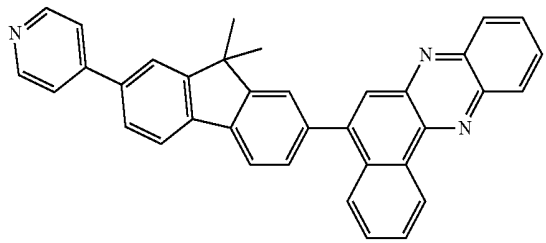

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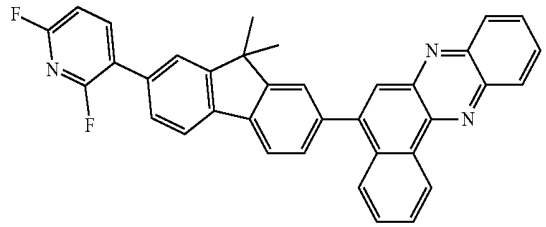

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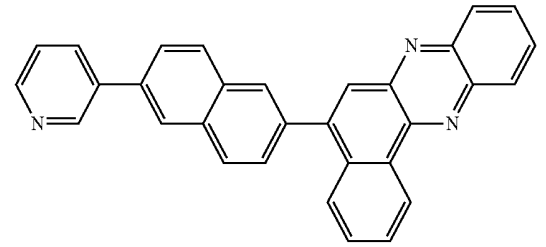

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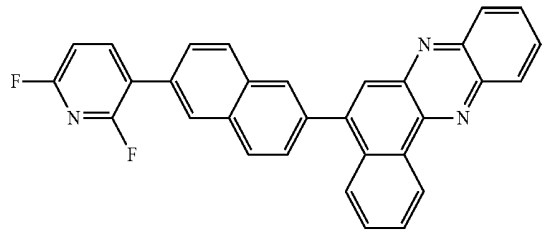

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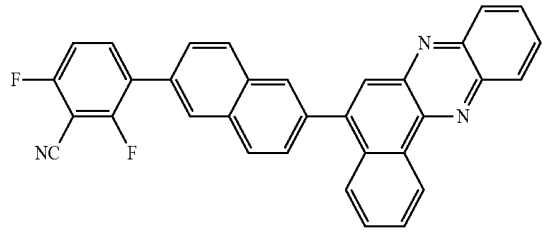

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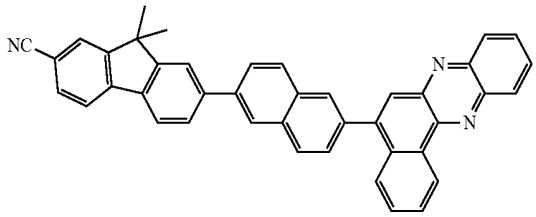

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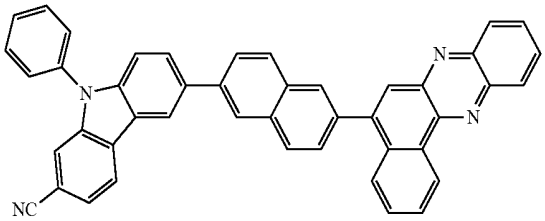

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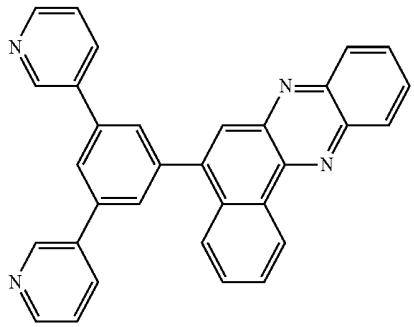

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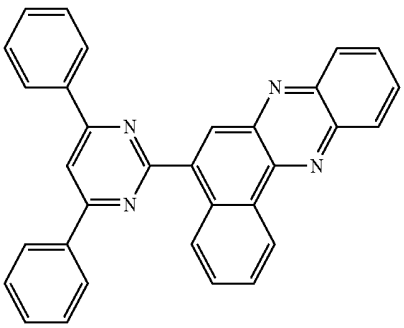

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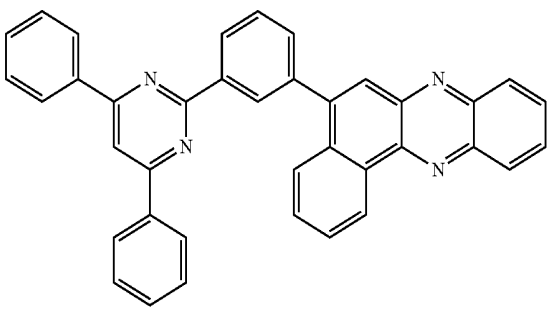

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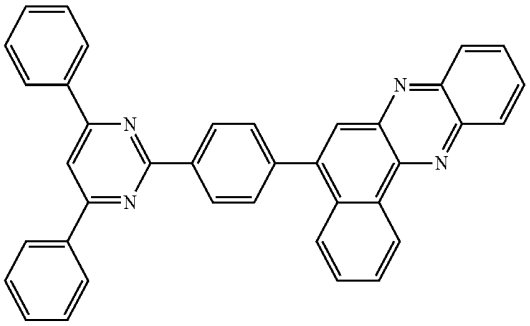

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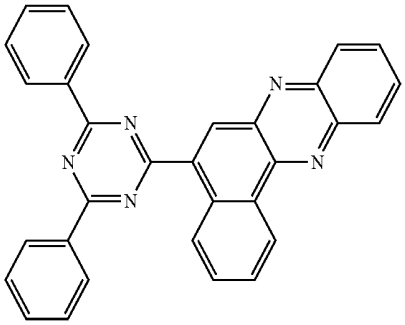

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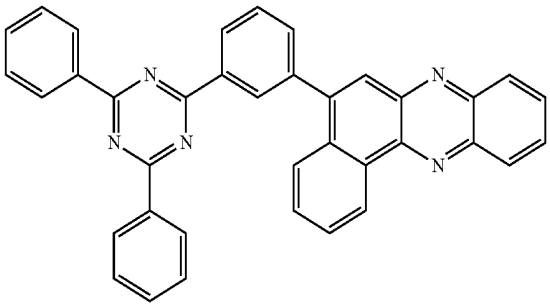

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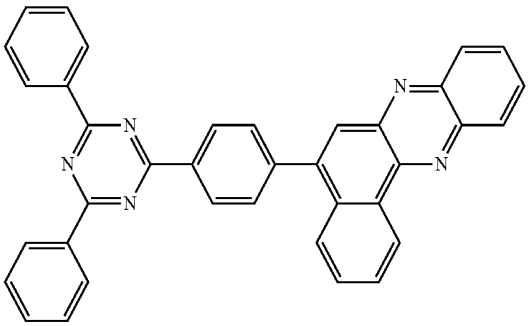

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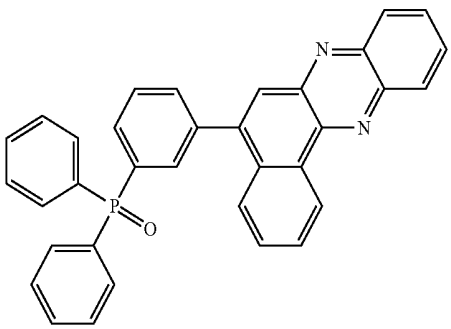

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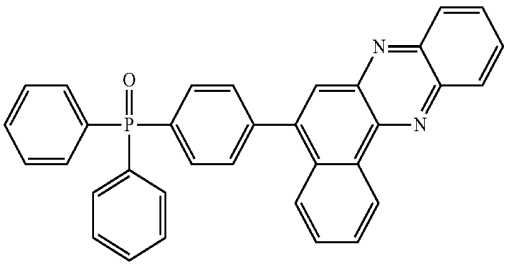

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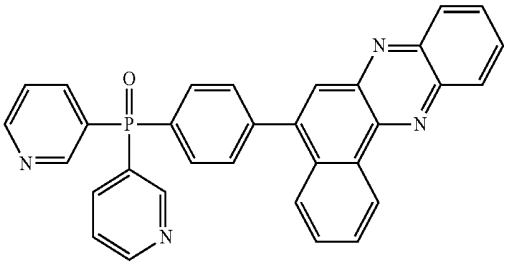

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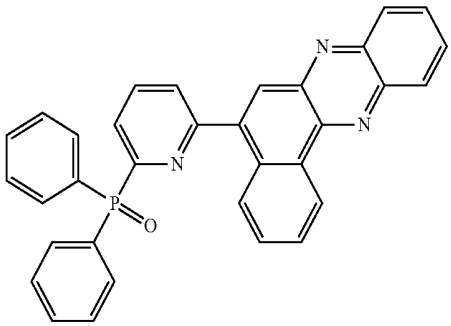

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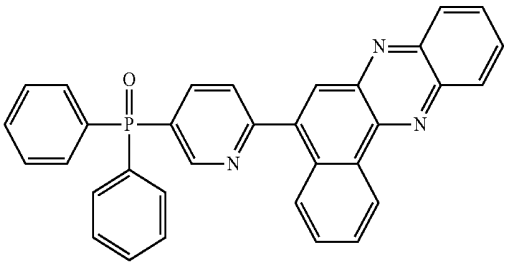

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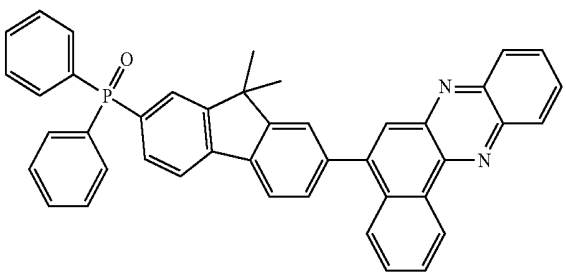

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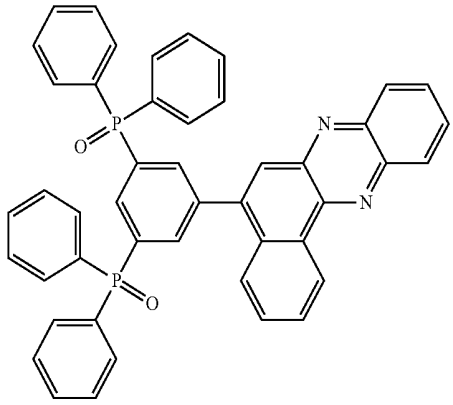

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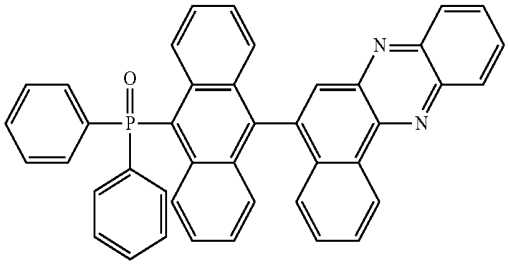

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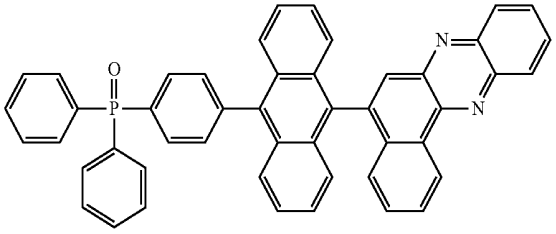

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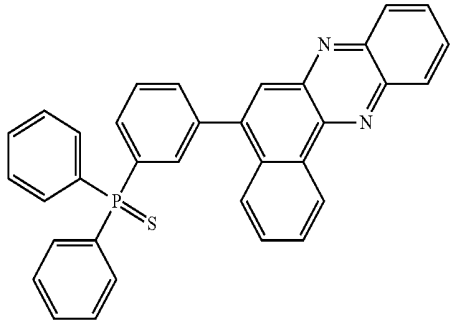

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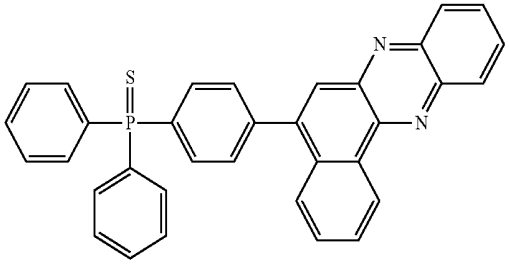

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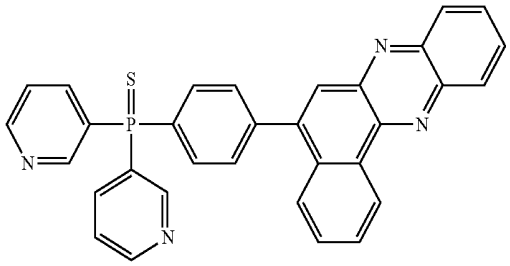

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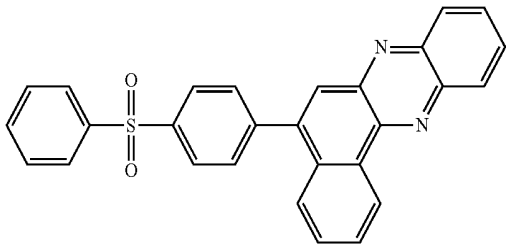

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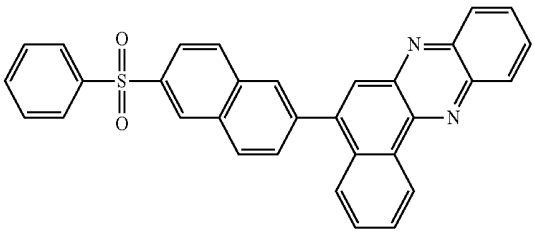

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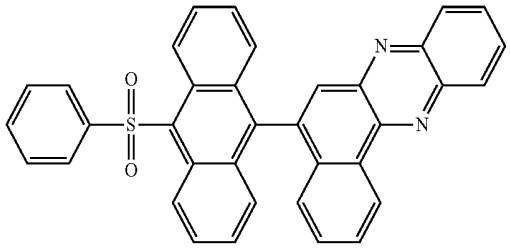

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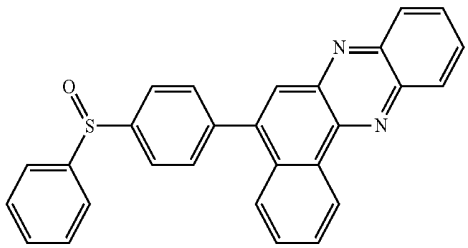

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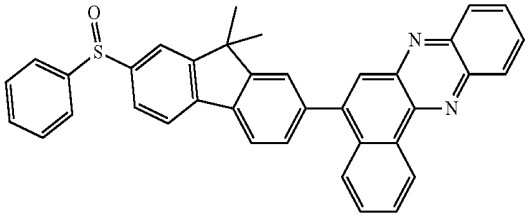

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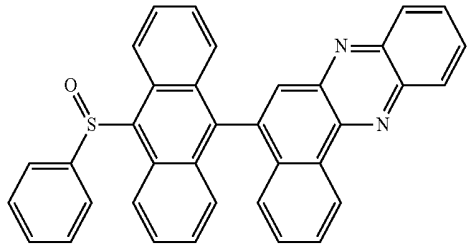


15. The organic light-emitting device of claim 1, wherein

the first electrode is an anode,

the second electrode is a cathode, and

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 at least one of a hole injection layer, a hole transport layer, a buffer layer, and an electron blocking layer, and

wherein the electron transport region comprises at least one of a hole blocking layer, an electron transport layer, and an electron injection layer.

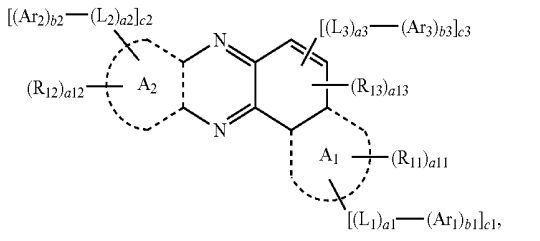
16. The organic light-emitting device of claim 1, wherein

the electron transport region comprises an electron transport layer, and

the electron transport layer comprises at least one of the condensed cyclic compounds.

17. A condensed cyclic compound represented by Formula 1:

<Formula 1>



wherein A_1 and A_2 in Formula 1 are each independently selected from a benzene group, a naphthalene group, a quinoline group, an isoquinoline group, or a quinazoline group,

L_1 to L_3 in Formula 1 are each independently 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, a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group, *—P(=O)(Q_4)-*', *—P(=S)(Q_4)-*', or *—S(=O)—*'

a1 and a2 in Formula 1 are each independently an integer selected from 0 to 7, and a3 is an integer selected from 1 to 7, wherein when a1 is 2 or greater, at least two L_1(s) are the same or different from each other, when a2 is 2 or greater, at least two L_2(s) are the same or different from each other, and when a3 is 2 or greater, at least two L_3(s) are the same or different from each other,

Ar_1 to Ar_3 in Formula 1 are each independently selected from a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —P(=O)(Q_4)(Q_5), —P(=S)(Q_4)(Q_5), or —S(=O)(Q_4),

b1 to b3 in Formula 1 are each independently an integer selected from 1 to 7, wherein when b1 is two or greater, at least two Ar_1(s) are the same or different from each other, when b2 is two or greater, at least two Ar_2(s) are the same or different from each other, and when b3 is two or greater, at least two Ar_3(s) are the same or different from each other,

c1 and c2 in Formula 1 are each independently an integer selected from 0 to 6, and c3 is an integer selected from 1 to 2,

c1 to c3 satisfy the formula of c1+c2+c3>1,

R_{11}, R_{12}, and R_{13} in Formula 1 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, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, or —Si(Q_1)(Q_2)(Q_3),

a11 and a12 in Formula 1 are each independently an integer selected from 0 to 6, and a13 is an integer selected from 0 to 2, wherein when a11 is 2 or greater, at least two R_{11}(s) are the same or different from each other, when a12 is 2 or more, at least two R_{12}(s) are the same or different from each other, and when a13 is 2, two of R_{13}(s) are the same or different from each other, and

at least one substituent selected from a substituent(s) of the substituted C_3-C_{10} cycloalkylene group, the substituted C_1-C_{10} heterocycloalkylene group, the substituted C_3-C_{10} cycloalkenylene group, the substituted C_1-C_{10} heterocycloalkenylene group, the substituted C_6-C_{60} arylene group, the substituted C_1-C_{60} heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, the substituted divalent non-aromatic

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

deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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, or a substituted or unsubstituted C_1-C_{60} alkoxy group;

a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $—Si(Q_{11})(Q_{12})(Q_{13})$, $—N(Q_{11})(Q_{12})$, $—B(Q_{11})(Q_{12})$, $—C(=O)(Q_11)$, $—S(=O)_2(Q_{11})$, or $—P(=O)(Q_11)(Q_{12})$;

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

a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic 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 C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{60} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $—Si(Q_{21})(Q_{22})(Q_2)$, $—N(Q_{21})(Q_{22})$, $—B(Q_{21})(Q_{22})$, $—C(=O)(Q_{21})$, $—S(=O)_2(Q_21)$, or $—P(=O)(Q_2)(Q_{22})$; and

$—Si(Q_{31})(Q_{32})(Q_{33})$, $—N(Q_{31})(Q_{32})$, $—B(Q_{31})(Q_{32})$, $—C(=O)(Q_{31})$, $—S(=O)_2(Q_{31})$, or $—P(=O)(Q_{31})(Q_{32})$,

wherein Q_1 to Q_5, Q_{21} to Q_{23}, and Q_{31} to Q_{33} 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_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, or a terphenyl group, and wherein

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

* * * * *

专利名称(译)	稠合环状化合物和包括该稠合环状化合物的有机发光装置		
公开(公告)号	US10553799	公开(公告)日	2020-02-04
申请号	US15/395801	申请日	2016-12-30
[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	PARK JUNHA KIM YOUNGKOOK SIM MUNKI LEE HYOYOUNG JEONG EUNJAE HWANG SEOKHWAN		
发明人	PARK, JUNHA KIM, YOUNGKOOK SIM, MUNKI LEE, HYOYOUNG JEONG, EUNJAE HWANG, SEOKHWAN		
IPC分类号	H01L51/00 C07F9/6558 C09K11/06 C07D401/14 C07D401/10 C07D405/10 H01L51/50 C07D409/10 C07D405/04 C07D403/10 C07D403/04 C07F9/6509 C07D241/38		
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审查员(译)	杨，JAY		
优先权	1020160076609 2016-06-20 KR		
其他公开文献	US20170365794A1		
外部链接	Espacenet		

摘要(译)

由式1表示的稠合环状化合物和包括该稠合环状化合物的有机发光装置。

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