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

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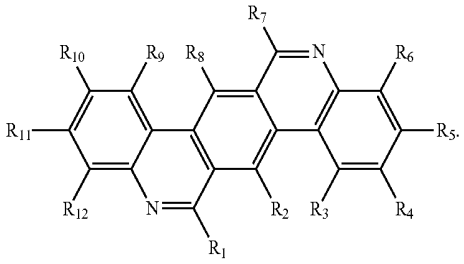
(57) **ABSTRACT**

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

<Formula 1>



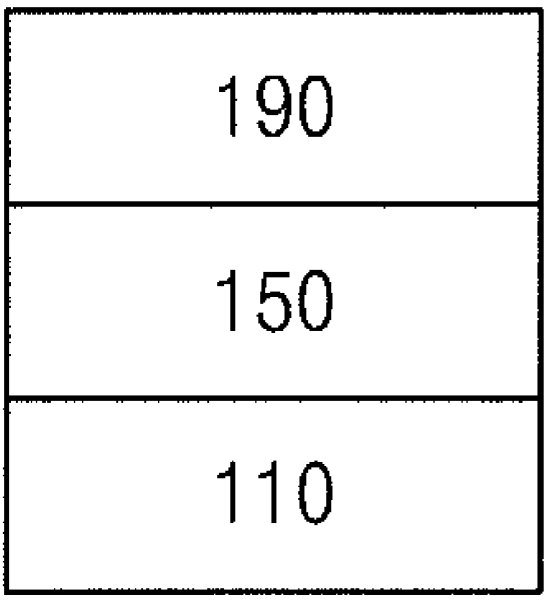


FIG. 1

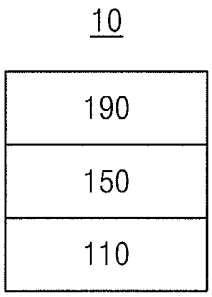
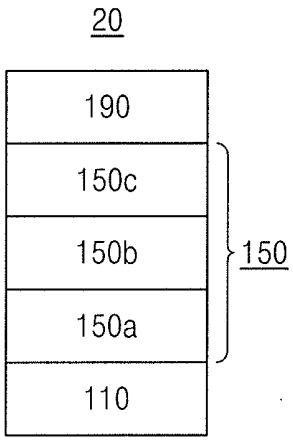


FIG. 2



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

CROSS-REFERENCE TO RELATED APPLICATION

[0001] Korean Patent Application No. 10-2016-0168009, filed on Dec. 9, 2016, in the Korean Intellectual Property Office, and entitled: "Condensed Cyclic Compound and Organic Light-Emitting Device Including the Same," is incorporated by reference herein in its entirety.

BACKGROUND

1. Field

[0002] Embodiments relate to a condensed cyclic compound for an organic light-emitting device and an organic light-emitting device including the same.

2. Description of the Related Art

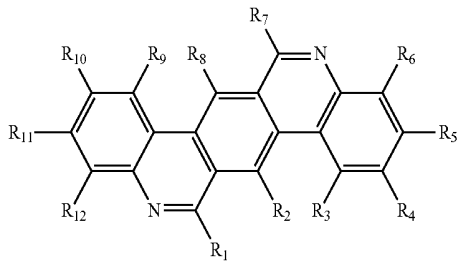
[0003] Organic light-emitting devices are self-emission devices that have wide viewing angles, high contrast ratios, short response times, and excellent characteristics in terms of brightness, driving voltage, and response speed, compared to devices in the art.

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

SUMMARY

[0005] The embodiments may be realized by providing a condensed cyclic compound represented by Formula 1:

<Formula 1>



[0006] wherein, in Formula 1, R_1 to R_{12} are each independently a group represented by Formula 2, 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, or a substituted or unsubstituted C_1-C_{60} alkoxy group, provided that at least one of R_1 to R_{12} is not hydrogen,

$$*\text{-}(L_1)_{a1}\text{-}(Ar_1)_{b1}, \qquad \text{<Formula 2>}$$

[0007] wherein, in Formula 2, L_1 is a substituted or unsubstituted C_3-C_{60} carbocyclic group, a substituted or unsubstituted C_1-C_{60} heterocyclic group, *—$Si(Q_1)(Q_2)$-*', *—$N(Q_1)$-*', *—$B(Q_1)$-*', *—$C(=O)$—*', *—$S(=O)_2$—*', or *—$P(=O)(Q_1)$-*', a1 is an integer of 0 to 4, wherein, when a1 is zero, *-$(L_1)_{a1}$-*' is a single bond, and when a1 is 2, 3, or 4, the 2, 3, or 4 L_1(s) are identical to or different from each other, Ar_1 is a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —$Si(Q_1)(Q_2)(Q_3)$, —$N(Q_1)(Q_2)$, —$B(Q_1)(Q_2)$, —$C(=O)(Q_1)$, —$S(=O)_2(Q_1)$, or —$P(=O)(Q_1)(Q_2)$, b1 is an integer of 1 to 4, wherein, when b1 is 2, 3, or 4, the 2, 3, or 4 Ar_1(s) are identical to or different from each other, at least one substituent of the substituted C_3-C_{60} carbocyclic group, the substituted C_1-C_{60} heterocyclic 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, and the substituted monovalent non-aromatic condensed heteropolycyclic group is selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group; a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, 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, —$Si(Q_{11})(Q_{12})(Q_{13})$, —$N(Q_{11})(Q_{12})$, —$B(Q_{11})(Q_{12})$, —$C(=O)(Q_{11})$, —$S(=O)_2(Q_{11})$, and —$P(=O)(Q_{11})(Q_{12})$; a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} 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, a biphenyl group, and a terphenyl 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, 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_{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, a biphenyl group, a terphenyl group, —$Si(Q_{21})(Q_{22})(Q_{23})$, —$N(Q_{21})(Q_{22})$, —$B(Q_{21})(Q_{22})$, —$C(=O)(Q_{21})$, —$S(=O)_2(Q_{21})$, and —$P(=O)(Q_{21})(Q_{22})$; and —$Si(Q_{31})(Q_{32})(Q_{33})$, —$N(Q_{31})(Q_{32})$, —$B(Q_{31})(Q_{32})$, —$C(=O)(Q_{31})$, —$S(=O)_2(Q_{31})$, and —$P(=O)(Q_{31})(Q_{32})$, Q_1 to Q_3, 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_6-C_{60} aryl group substituted with a C_1-C_{60} alkyl 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, and a terphenyl group, and * and *' each indicate a binding site to a neighboring atom.

[0008] The embodiments may be realized by providing an organic light-emitting device including a first electrode; a second electrode facing the first electrode; and an organic layer between the first electrode and the second electrode, the organic layer comprising an emission layer, wherein the organic layer includes the condensed cyclic compound according to an embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Features will be apparent to those of skill in the art by describing in detail exemplary embodiments with reference to the attached drawings in which:

[0010] FIG. **1** illustrates a schematic view of an organic light-emitting device according to an embodiment; and

[0011] FIG. **2** illustrates a schematic view of an organic light-emitting device according to an embodiment.

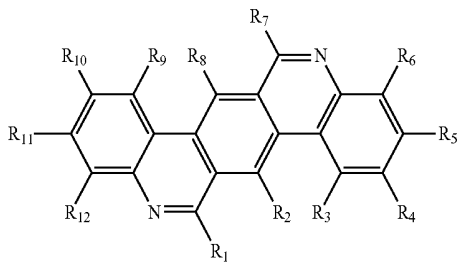
DETAILED DESCRIPTION

[0012] Example embodiments will now be described more fully hereinafter with reference to the accompanying drawings; however, they may be embodied in different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey exemplary implementations to those skilled in the art.

[0013] In the drawing figures, the dimensions of layers and regions may be exaggerated for clarity of illustration. It will also be understood that when a layer or element is referred to as being "on" another layer or element, it can be directly on the other layer or element, or intervening layers may also be present. In addition, it will also be understood that when a layer is referred to as being "between" two layers, it can be the only layer between the two layers, or one or more intervening layers may also be present. As used herein, the term "or" is not an exclusive term, e.g., A or B includes A, B, or A and B. Like reference numerals refer to like elements throughout.

[0014] A condensed cyclic compound according to an embodiment is represented by Formula 1:

<Formula 1>



[0015] R_1 to R_{12} may each independently be, e.g., a group represented by Formula 2, 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, or a substituted or unsubstituted C_1-C_{60} alkoxy group. In an implementation, at least one of R_1 to R_{12} is not hydrogen. In an implementation, at least one of R_1 to R_{12} in Formula 1 may be a group represented by Formula 2.

$$*\text{-}(L_1)_{a1}\text{-}(Ar_1)_{b1}. \qquad \text{<Formula 2>}$$

[0016] In Formulae 1 and 2,

[0017] L_1 may be selected from or include, e.g., a substituted or unsubstituted C_3-C_{60} carbocyclic group, a substituted or unsubstituted C_1-C_{60} heterocyclic group, *—$Si(Q_1)(Q_2)$-*', *—$N(Q_1)$-*', *—$B(Q_1)$-*', *—$C(=O)$—*', *—$S(=O)_2$—*', and *—$P(=O)(Q_1)$-*'.

[0018] In an implementation, L_1 may be selected from:

[0019] a benzene group, a pentalene group, an indene group, a naphthalene group, an azulene group, a heptalene group, an indacene group, an acenaphthalene group, a fluorene group, a spiro-bifluorene group, a spiro-benzofluorene-fluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pyrrole group, a thiophene group, a furan group, a silole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a triazine group, a benzofuran group, a benzothiophene group, a benzosilole group, a dibenzofuran group, a dibenzothiophene group, a dibenzosilole group, a carbazole group, a quinoline group, an isoquinoline group, a benzocarbazole

group, a dibenzocarbazole group, a benzimidazole group, an imidazopyridine group, and an imidazopyrimidine group;

[0020] a benzene group, a pentalene group, an indene group, a naphthalene group, an azulene group, a heptalene group, an indacene group, an acenaphthalene group, a fluorene group, a spiro-bifluorene group, a spiro-benzofluorene-fluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pyrrole group, a thiophene group, a furan group, a silole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a triazine group, a benzofuran group, a benzothiophene group, a benzosilole group, a dibenzofuran group, a dibenzothiophene group, a dibenzosilole group, a carbazole group, a quinoline group, an isoquinoline group, a benzocarbazole group, a dibenzocarbazole group, a benzimidazole group, an imidazopyridine group, and an imidazopyrimidine group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a carbazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, $—Si(Q_{31})(Q_{32})(Q_{33})$, $—N(Q_{31})(Q_{32})$, and $—B(Q_{31})(Q_{32})$; and

[0021] *—$S(=O)_2$—*' and *—$P(=O)(Q_1)$-*',

[0022] Q_1 and Q_{31} to Q_{33} may each independently be selected from, e.g., a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and a pyridinyl group, and

[0023] * and *' each indicate a binding site to a neighboring atom.

[0024] In an implementation, L_1 may be selected from:

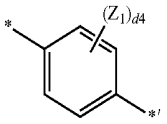
[0025] a benzene group, a naphthalene group, an anthracene group, a fluorene group, a spiro-bifluorene group, a pyridine group, a pyrimidine group, a triazine group, a carbazole group, a quinoline group, and an isoquinoline group;

[0026] a benzene group, a naphthalene group, an anthracene group, a fluorene group, a spiro-bifluorene group, a pyridine group, a pyrimidine group, a triazine group, a carbazole group, a quinoline group, and an isoquinoline group, each substituted with at least one selected from a cyano group, a C_1-C_{20} alkyl group, a phenyl group, a biphenyl group, a pyridinyl group, and a fluorenyl group; and

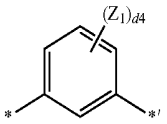
[0027] *—$S(=O)_2$—*' and *—$P(=O)(Q_1)$-*'.

[0028] In an implementation, L_1 may be, e.g., a group represented by one of Formulae 3-1 to 3-31, 3-31', 3-32', and 3-32 to 3-35.

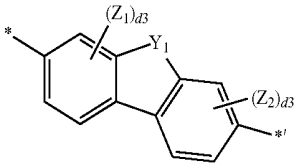
Formula 3-1



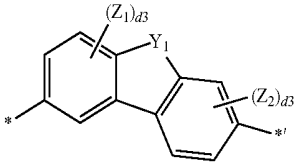
Formula 3-2



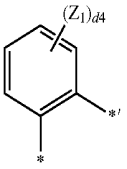
Formula 3-3



Formula 3-4



Formula 3-5



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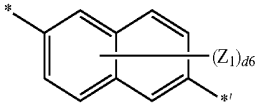
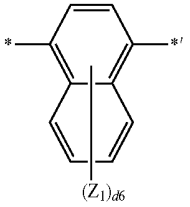


Formula 3-7



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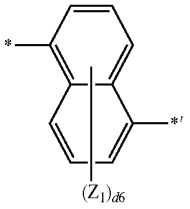

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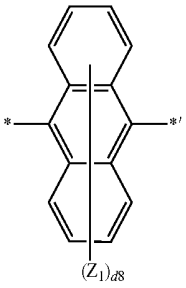
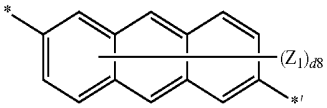
Formula 3-9



Formula 3-10



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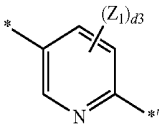
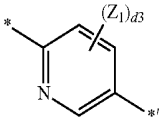
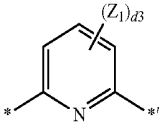


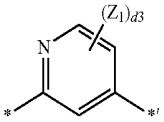
Formula 3-12



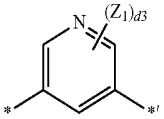
Formula 3-13



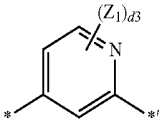
Formula 3-14



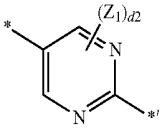
Formula 3-15



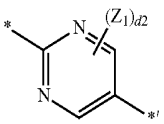
Formula 3-16



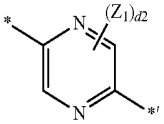
Formula 3-17



Formula 3-18



Formula 3-19



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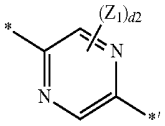
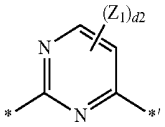
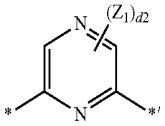
Formula 3-20



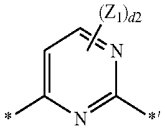
Formula 3-21



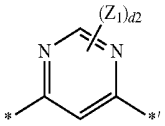
Formula 3-22



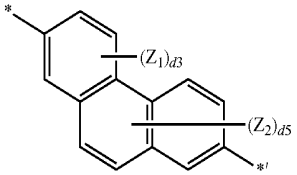
Formula 3-23



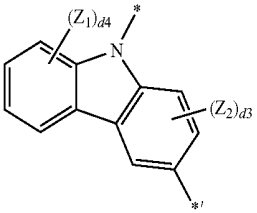
Formula 3-24



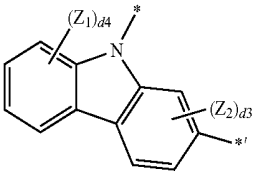
Formula 3-25



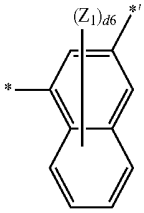
Formula 3-26



Formula 3-27



Formula 3-28



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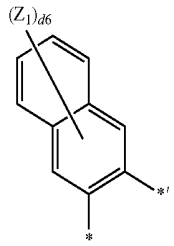
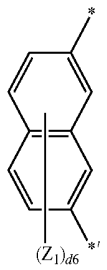
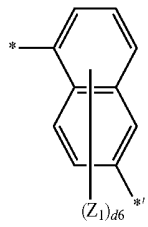
Formula 3-29



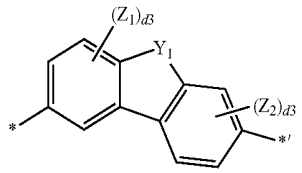
Formula 3-30



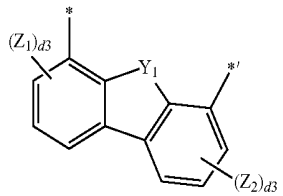
Formula 3-31



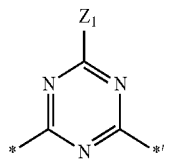
Formula 3-32



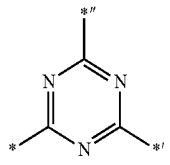
Formula 3-31′



Formula 3-32′



Formula 3-33



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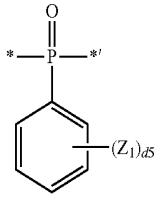
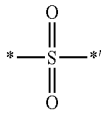
Formula 3-34



Formula 3-35



[0029] In Formulae 3-1 to 3-31, 3-31', 3-32', and 3-32 to 3-35,

[0030] Y_1 may be, e.g., O, S, $C(Z_3)(Z_4)$, $N(Z_5)$, or $Si(Z_6)(Z_7)$,

[0031] Z_1 to Z_7 may each independently be selected from, e.g., deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a 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 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, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, and —$Si(Q_{31})(Q_{32})(Q_{33})$,

[0032] Q_{31} to Q_{33} may each independently be selected from, e.g., a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and a pyridinyl group,

[0033] d2 may be an integer of 0 to 2,

[0034] d3 may be an integer of 0 to 3,

[0035] d4 may be an integer of 0 to 4,

[0036] d5 may be an integer of 0 to 5,

[0037] d6 may be an integer of 0 to 6,

[0038] d8 may be an integer of 0 to 8, and

[0039] *, *', and *'' each indicate a binding site to a neighboring atom. For example, when a variable is 0, e.g., when d2 is 0, hydrogen atoms are present in place of Z_{31}.

[0040] a1 in Formulae 1 and 2 may be an integer of 0 to 4, wherein, when a1 is 0, *-$(L_1)_{a1}$-*' may be a single bond, and when a1 is 2, 3, or 4, the 2, 3, or 4 L_1(s) may be identical to or different from each other.

[0041] Ar_1 in Formula 2 may be selected from or include, e.g., a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or

unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —$Si(Q_1)(Q_2)(Q_3)$, —$N(Q_1)(Q_2)$, —$B(Q_1)(Q_2)$, —$C(=O)(Q_1)$, —$S(=O)_2(Q_1)$, and —$P(=O)(Q_1)(Q_2)$.

[0042] In an implementation, Ar_1 may be selected from:

[0043] a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a thiophenyl group, a furanyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzonaphthofuranyl group, a dinaphthofuranyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a benzonaphthosilolyl group, a dinaphthosilolyl group, a benzimidazolyl group, and an imidazopyridinyl group;

[0044] a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a thiophenyl group, a furanyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzonaphthofuranyl group, a dinaphthofuranyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a benzonaphthosilolyl group, a dinaphthosilolyl group, a benzimidazolyl group, and an imidazopyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a thiophenyl group, a furanyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, —$N(Q_{31})(Q_{32})$, and —$Si(Q_{31})(Q_{32})(Q_{33})$; and

[0045] —$S(=O)(Q_1)(Q_2)$, —$S(=O)_2(Q_1)$, —$P(=O)(Q_1)(Q_2)$, —$P(=O)_2(Q_1)$, —$P(=S)(Q_1)(Q_2)$, and —$P(=S)_2(Q_1)$.

[0046] In an implementation, Ar_1 may be selected from:

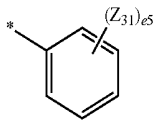
[0047] a phenyl group, a biphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a phenanthrenyl group, an anthracenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, and a carbazolyl group;

[0048] a phenyl group, a biphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a phenanthrenyl group, an anthracenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, and a carbazolyl 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 naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, —$N(Q_{31})(Q_{32})$, and —$Si(Q_{31})(Q_{32})(Q_{33})$; and

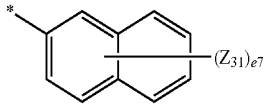
[0049] —$S(=O)(Q_1)(Q_2)$, —$S(=O)_2(Q_1)$, —$P(=O)(Q_1)(Q_2)$, —$P(=O)_2(Q_1)$, —$P(=S)(Q_1)(Q_2)$, and —$P(=S)_2(Q_1)$.

[0050] In an implementation, Ar_1 may be a group represented by one of Formulae 5-1 to 5-49, —$S(=O)(Q_1)(Q_2)$, —$S(=O)_2(Q_1)$, —$P(=O)(Q_1)(Q_2)$, —$P(=O)_2(Q_1)$, —$P(=S)(Q_1)(Q_2)$, or —$P(=S)_2(Q)$.

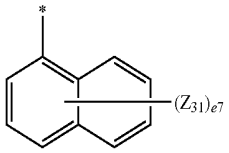
Formula 5-1



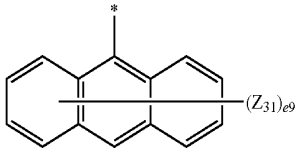
Formula 5-2



Formula 5-3



Formula 5-4



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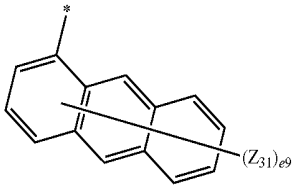
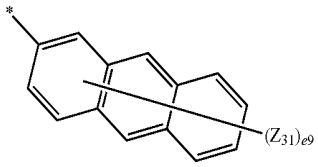
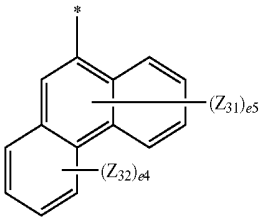
Formula 5-5



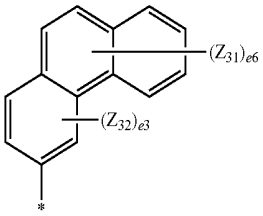
Formula 5-6



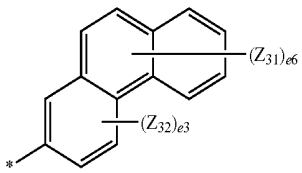
Formula 5-7



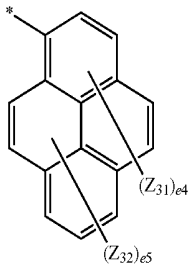
Formula 5-8



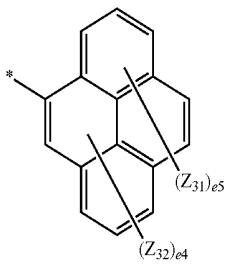
Formula 5-9



Formula 5-10



Formula 5-11



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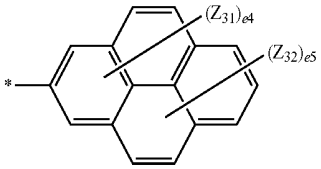
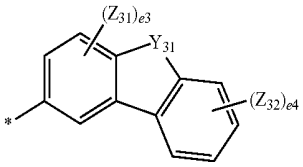
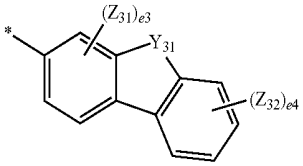
Formula 5-12



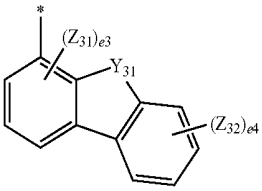
Formula 5-13



Formula 5-14



Formula 5-15



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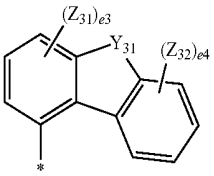
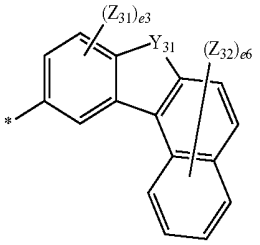


Formula 5-17



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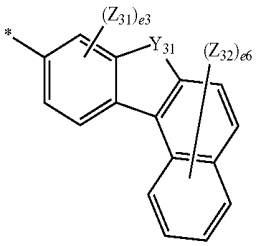

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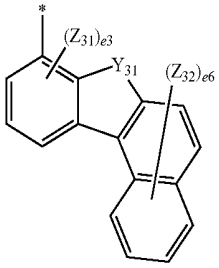

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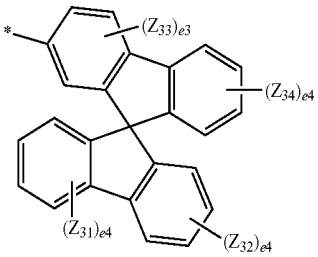

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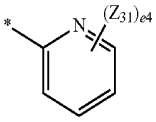

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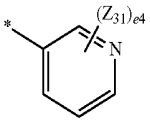

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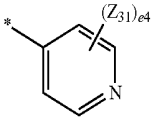

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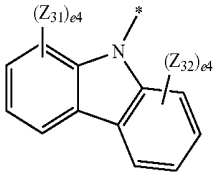
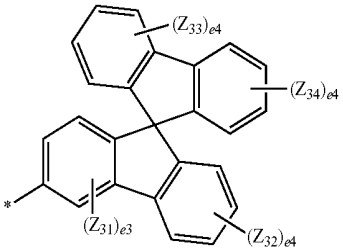
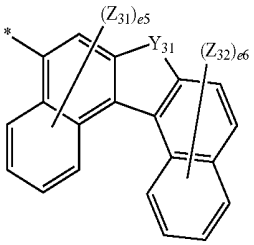


Formula 5-25



Formula 5-26



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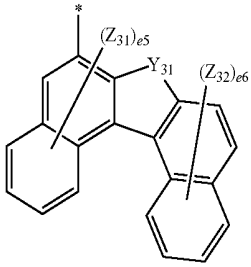
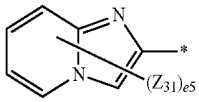
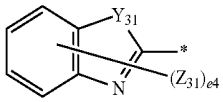
Formula 5-27



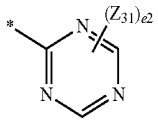
Formula 5-28



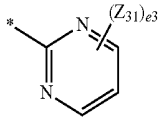
Formula 5-29



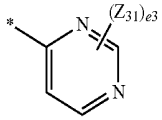
Formula 5-30



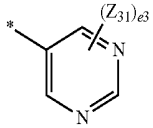
Formula 5-31



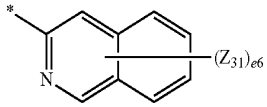
Formula 5-32



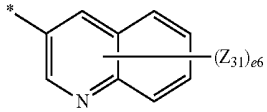
Formula 5-33



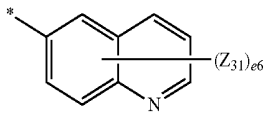
Formula 5-34



Formula 5-35



Formula 5-36



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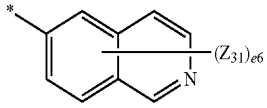

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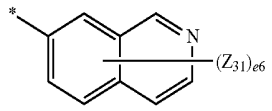
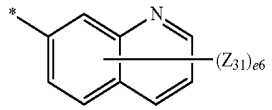
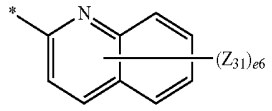
Formula 5-38



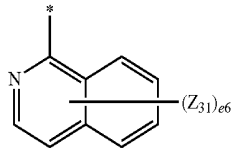
Formula 5-39



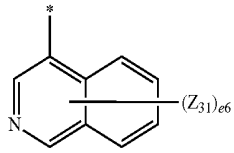
Formula 5-40



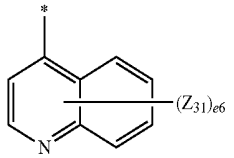
Formula 5-41



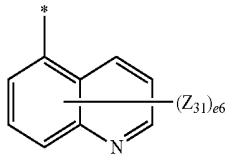
Formula 5-42



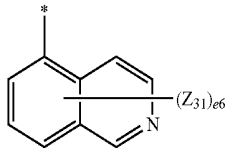
Formula 5-43



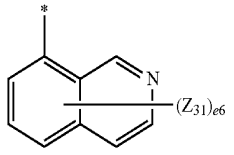
Formula 5-44



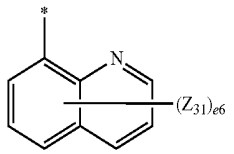
Formula 5-45



Formula 5-46



Formula 5-47



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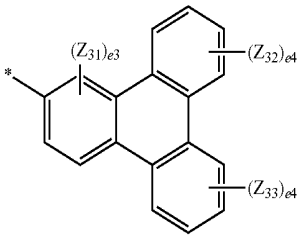
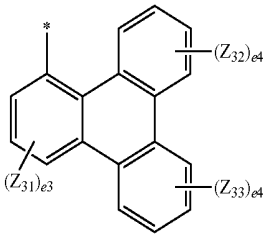
Formula 5-48



Formula 5-49



[0051] In Formulae 5-1 to 5-49,

[0052] Y_{31} may be, e.g., O, S, $C(Z_{33})(Z_{34})$, $N(Z_{35})$, or $Si(Z_{36})(Z_{37})$,

[0053] Z_{31} to Z_{37} may each independently be selected from, e.g., deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl group, a pyridinyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, and $—Si(Q_{31})(Q_{32})(Q_{33})$,

[0054] Q_1, Q_2, and Q_{31} to Q_{33} may each independently be selected from, e.g., a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, and a pyridinyl group,

[0055] e2 may be an integer of 0 to 2,

[0056] e3 may be an integer of 0 to 3,

[0057] e4 may be an integer of 0 to 4,

[0058] e5 may be an integer of 0 to 5,

[0059] e6 may be an integer of 0 to 6,

[0060] e7 may be an integer of 0 to 7,

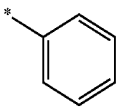
[0061] e9 may be an integer of 0 to 9, and

[0062] * indicates a binding site to a neighboring atom.

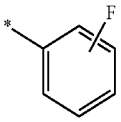
[0063] In an implementation, Ar_1 may be, e.g., a group represented by one of Formulae 5-1 to 5-4, 5-7, 5-13, 5-14, 5-20 to 5-23, 5-30, 5-31, 5-34, 5-41, and 5-48, $—S(=O)_2(Q_1)$, or $—P(=O)(Q_1)(Q_2)$.

[0064] In an implementation, Ar_1 may be, e.g., a group represented by one of Formulae 6-1 to 6-110, group represented by one of Formulae 10-1 to 10-11, —S(═O)$_2$(Q_1), or —P(═O)(Q_1)(Q_2).

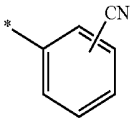
Formula 6-1



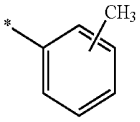
Formula 6-2



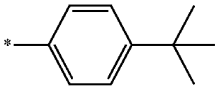
Formula 6-3



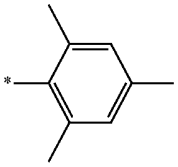
Formula 6-4



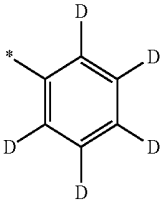
Formula 6-5



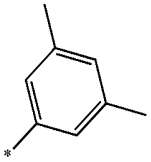
Formula 6-6



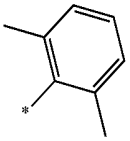
Formula 6-7



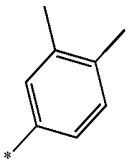
Formula 6-8



Formula 6-9



Formula 6-10



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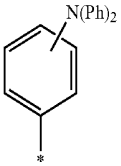
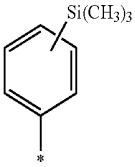
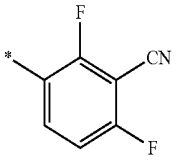
Formula 6-11



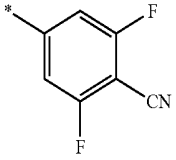
Formula 6-12



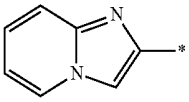
Formula 6-13



Formula 6-14



Formula 6-15



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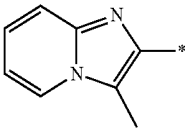

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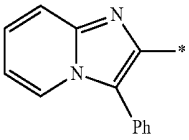

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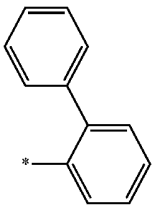

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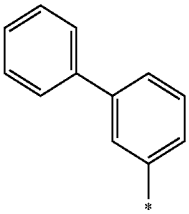

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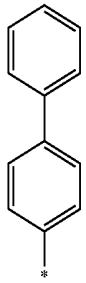

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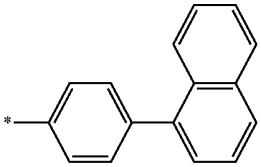

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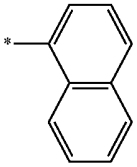

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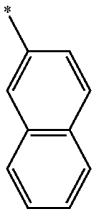

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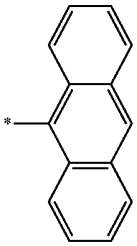

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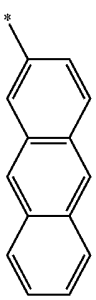

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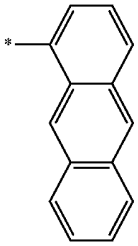

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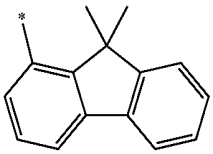

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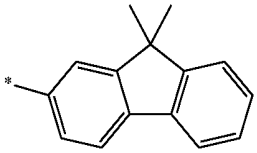

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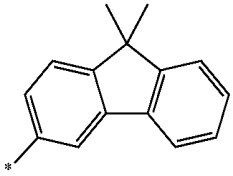

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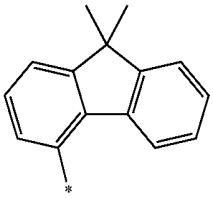

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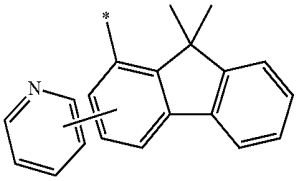

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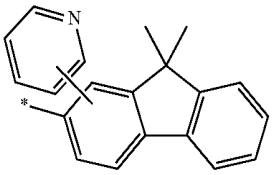

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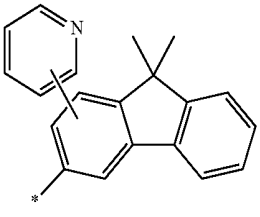

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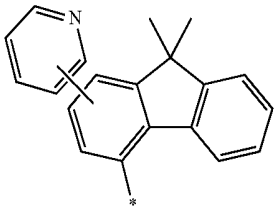

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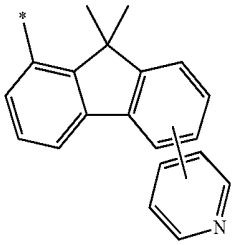

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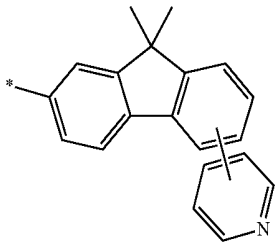

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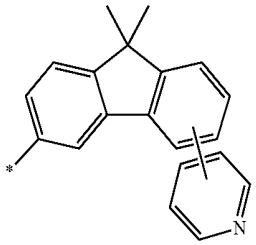

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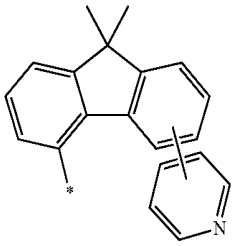

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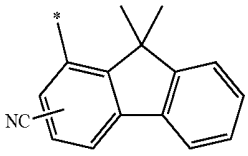

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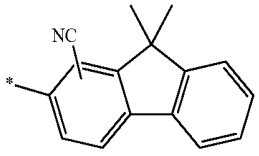

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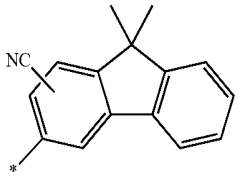

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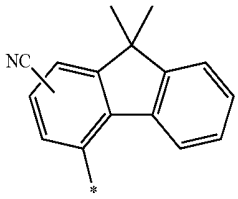

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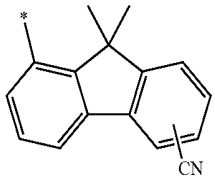

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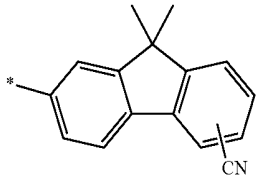

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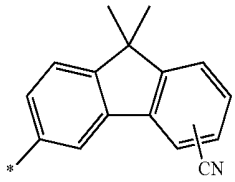

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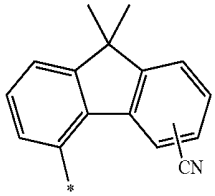

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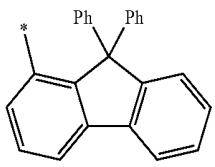

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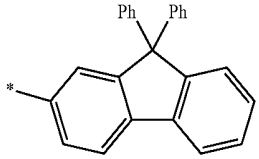

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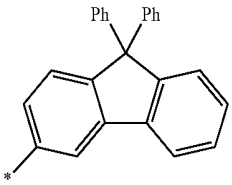

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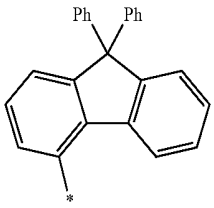

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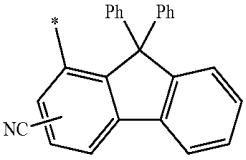

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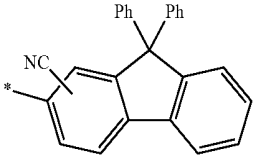

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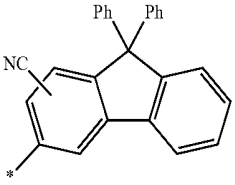

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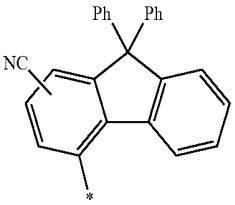

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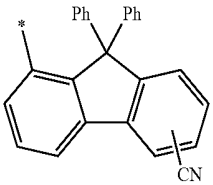

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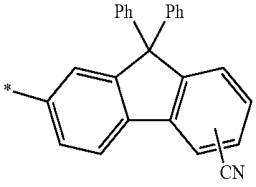

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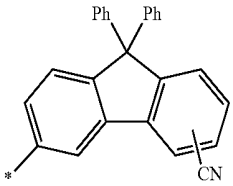

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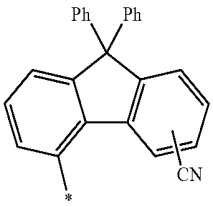

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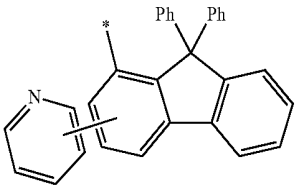

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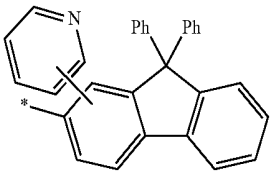

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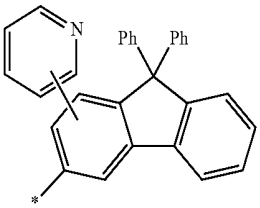

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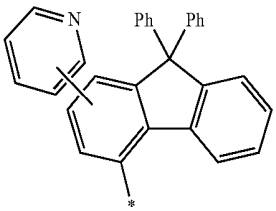

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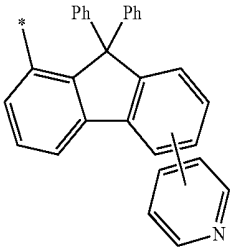

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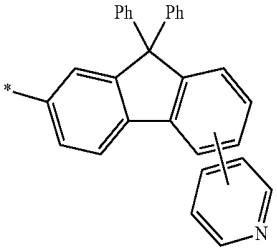

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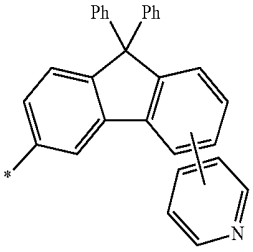

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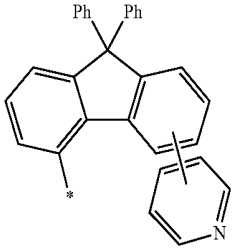

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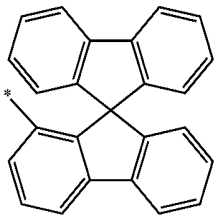

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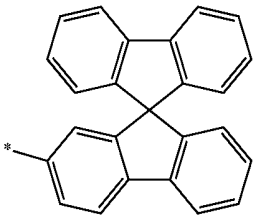

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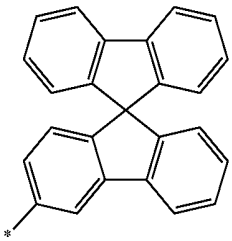

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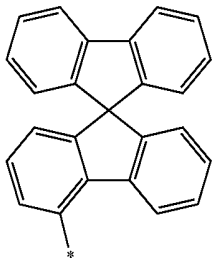

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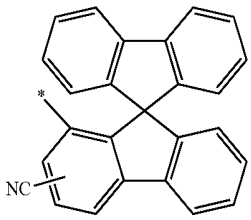
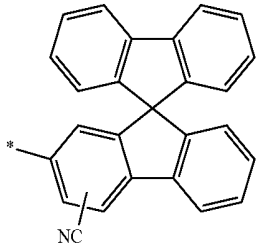


Formula 6-72



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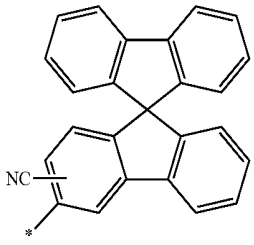

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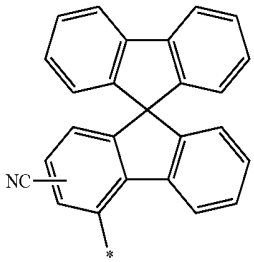

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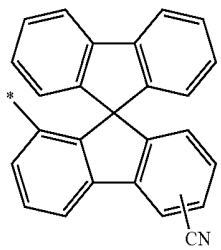

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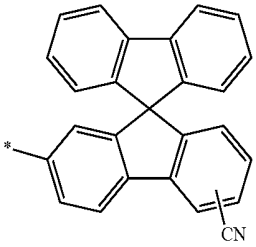

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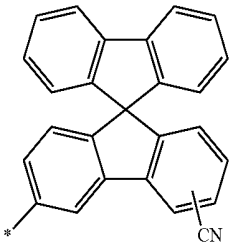

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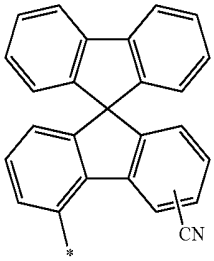

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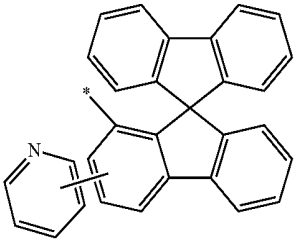

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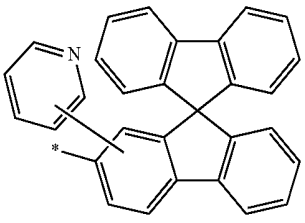

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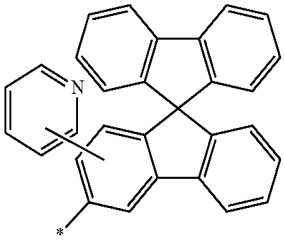

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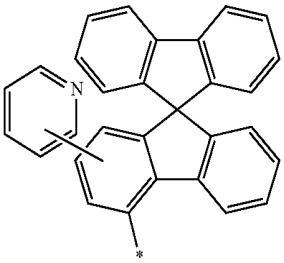

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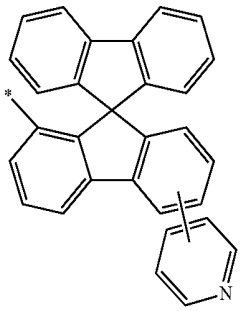

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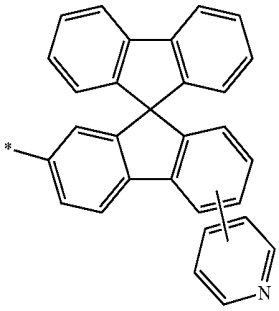

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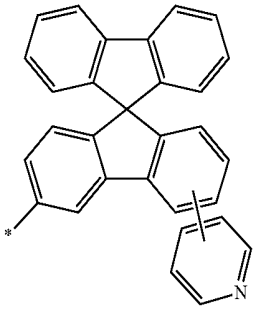

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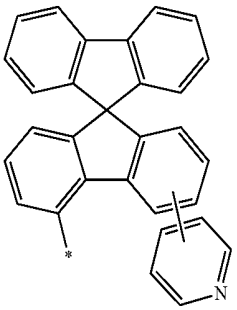

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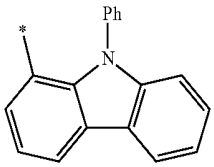

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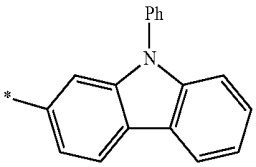

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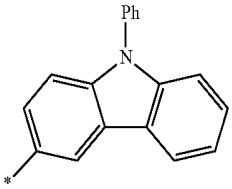

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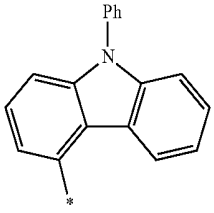

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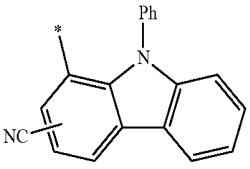

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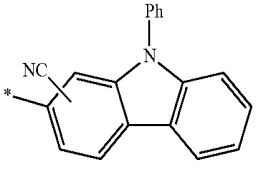

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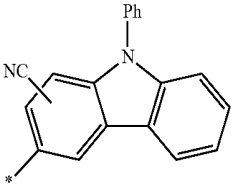

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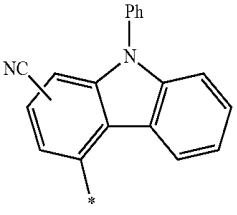

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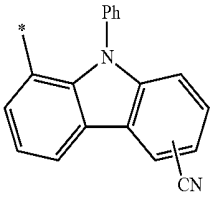

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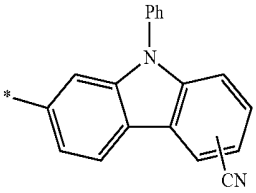

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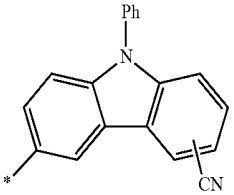

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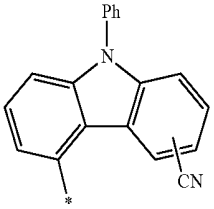

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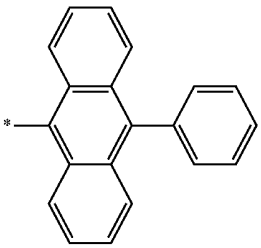

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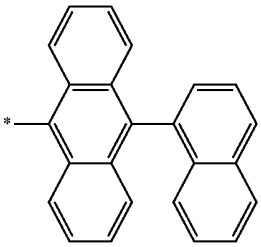

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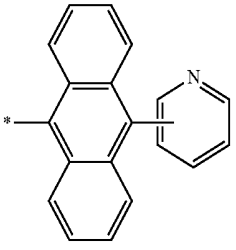

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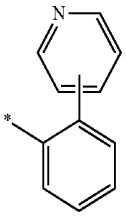

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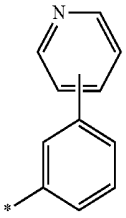

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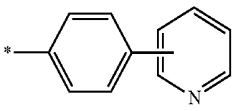

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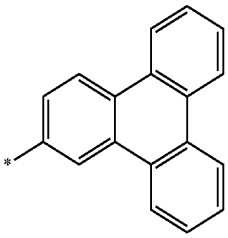

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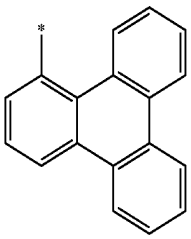

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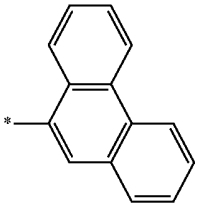

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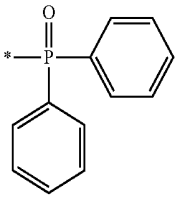

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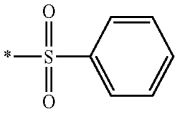

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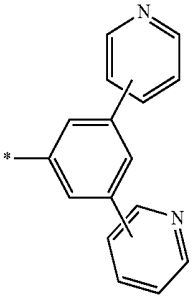
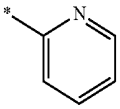
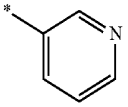


Formula 10-1



Formula 10-2



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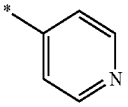

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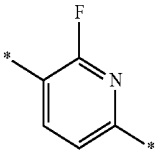
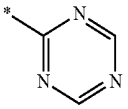
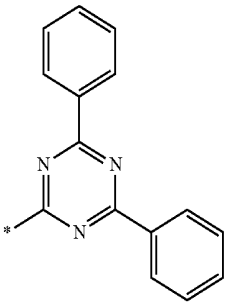


Formula 10-5



Formula 10-6



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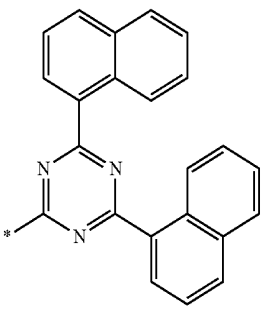

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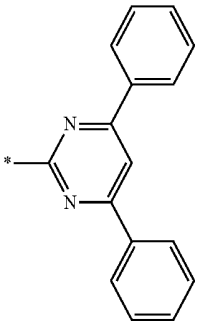
Formula 10-8



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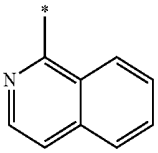
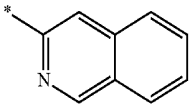
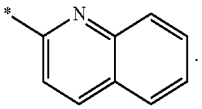


Formula 10-10



Formula 10-11



[0065] In Formulae 6-1 to 6-110 and 10-1 to 10-11, Ph indicates a phenyl group and * indicates a binding site to a neighboring atom.

[0066] In an implementation, Ar_1 may be, e.g., a group represented by one of Formulae 6-1 to 6-3, 6-22, 6-23, 6-36, 6-44, 6-56, 6-64, 6-76, 6-84, 6-96, 6-103 to 6-105, and 6-107 to 6-110 or a group represented by one of Formulae 10-1 to 10-3, 10-6, and 10-8 to 10-11.

[0067] In an implementation, in Formula 1, at least one of R_1, R_5, R_7, and R_{11} may be a group represented by Formula 2.

[0068] In an implementation, at least one of R_2 and R_8 may be a substituted or unsubstituted C_1-C_{60} alkyl group.

[0069] In an implementation, R_3, R_4, R_6, R_9, R_{10}, and R_{12} may each be hydrogen.

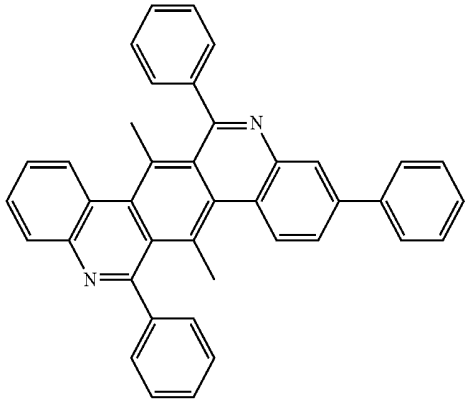
[0070] In an implementation, in Formula 1, i) R_1, R_5, and R_7 may each be a group represented by Formula 2, R_2 and R_8 may each be a substituted or unsubstituted C_1-C_{60} alkyl group, and R_3, R_4, R_6, R_9, R_{10}, R_{11}, and R_{12} may each be hydrogen.

[0071] In an implementation R_1, R_5, R_7, and R_{11} may each be a group represented by Formula 2, R_2 and R_8 may each be a substituted or unsubstituted C_1-C_{60} alkyl group, and R_3, R_4, R_6, R_9, R_{10}, and R_{12} may each be hydrogen.

[0072] In an implementation R_1 and R_7 may each be a group represented by Formula 2, R_2 and R_8 may each be a substituted or unsubstituted C_1-C_{60} alkyl group, and R_3, R_4, R_5, R_6, R_9, R_{10}, R_{11}, and R_{12} may each be hydrogen.

[0073] In an implementation, the condensed cyclic compound represented by Formula 1 may be one of the following Compounds 1 to 138.

1



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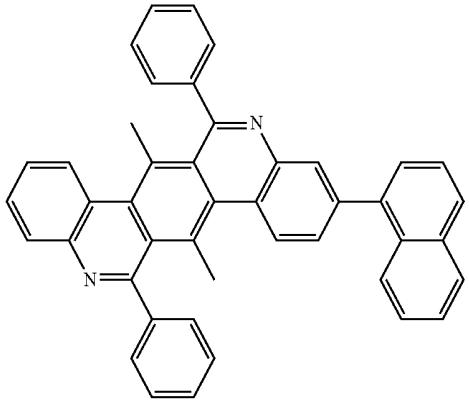

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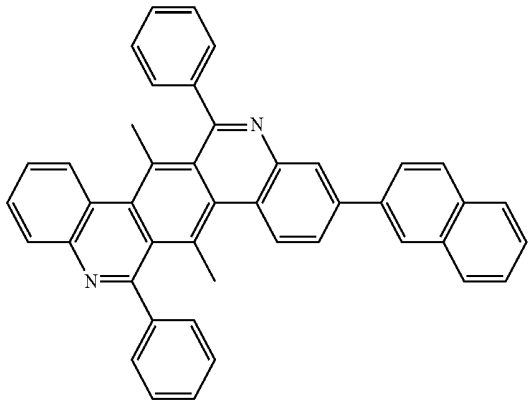

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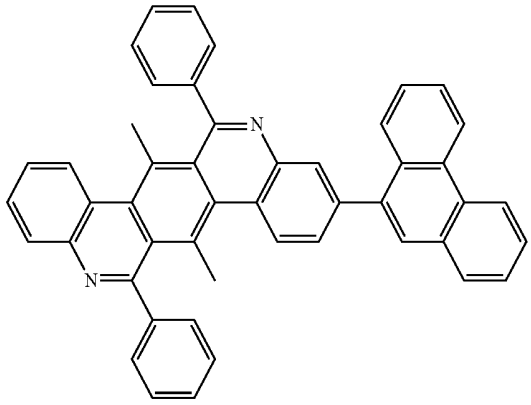

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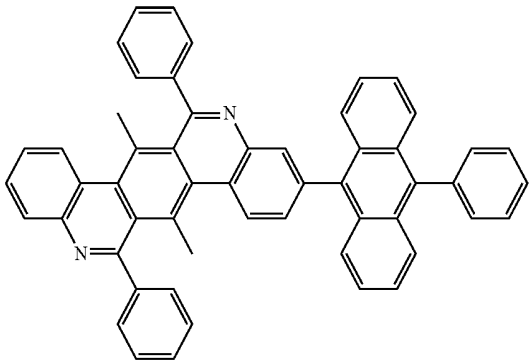

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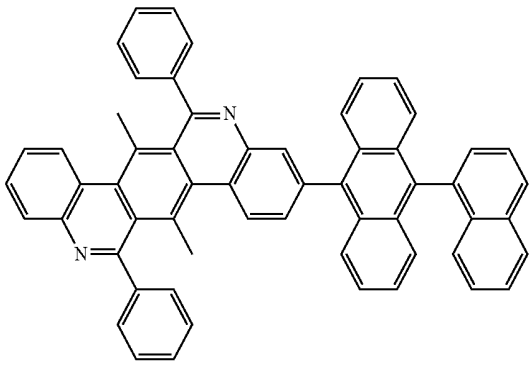

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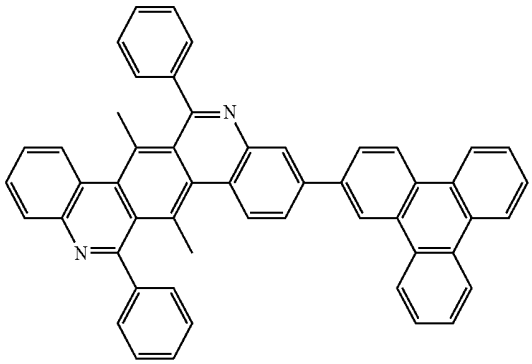

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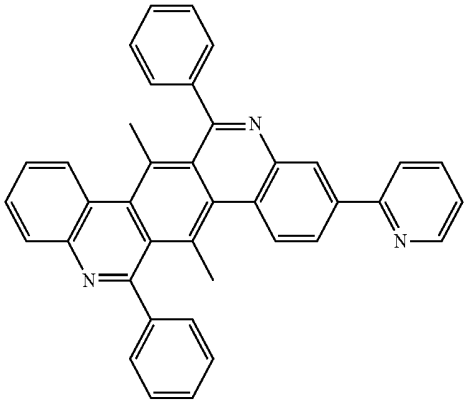

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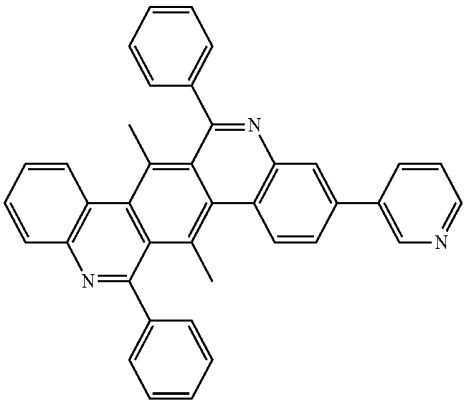

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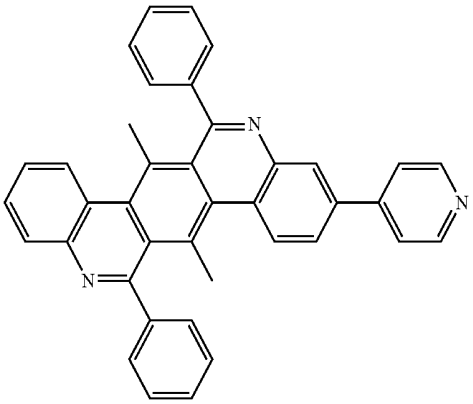

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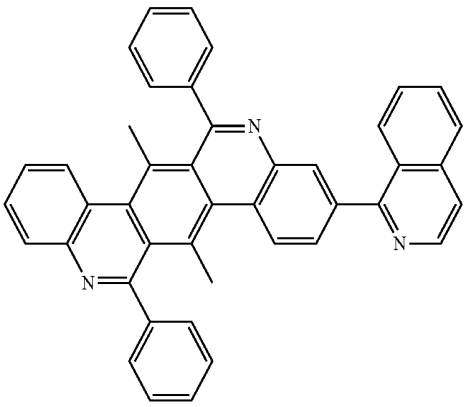

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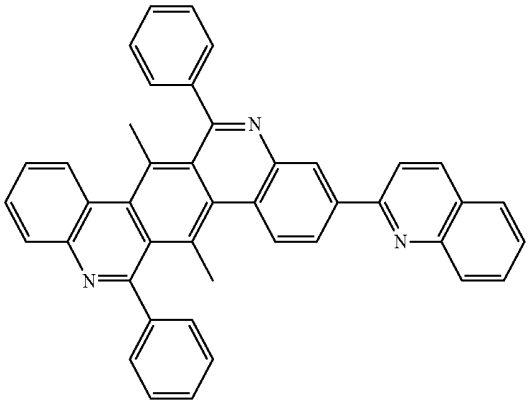

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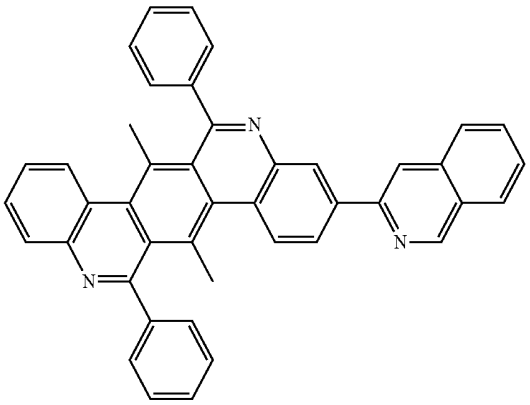

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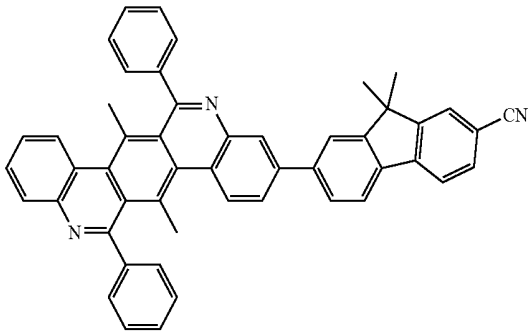

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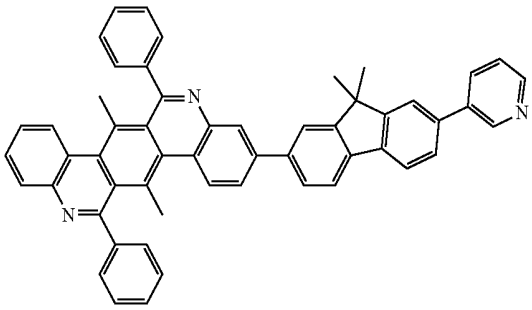

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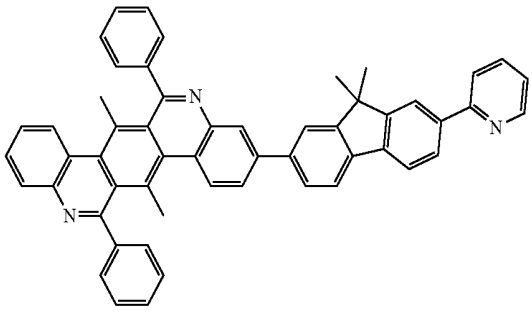

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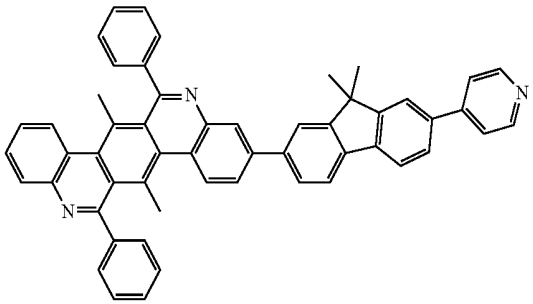

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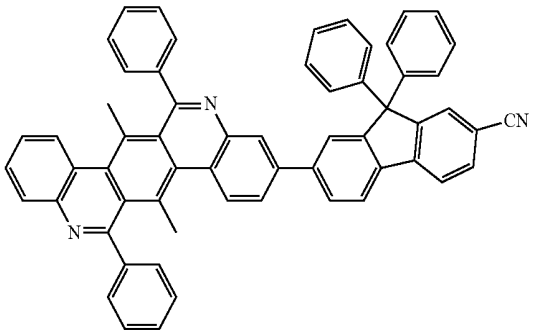

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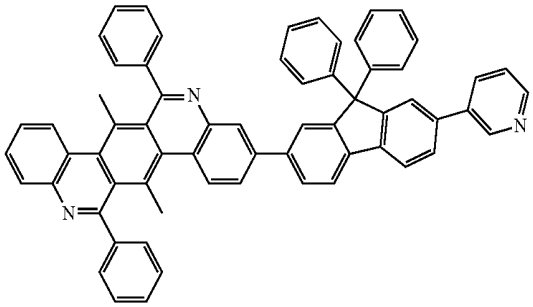

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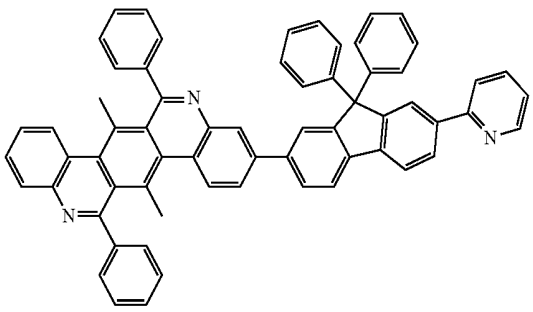

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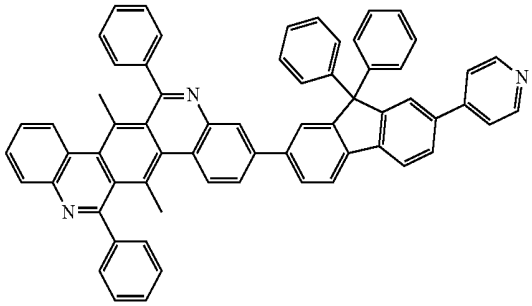

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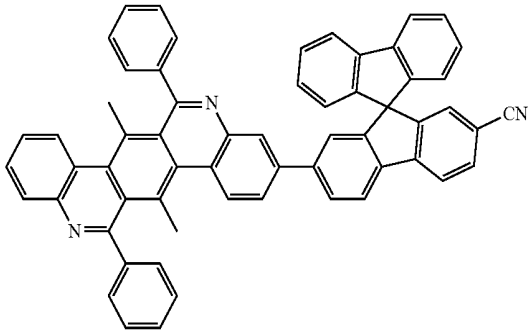

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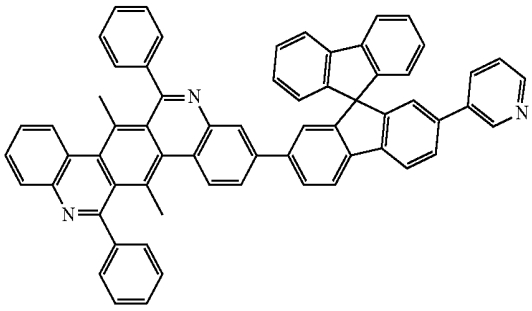

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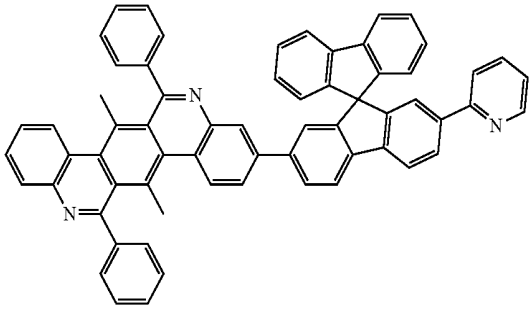

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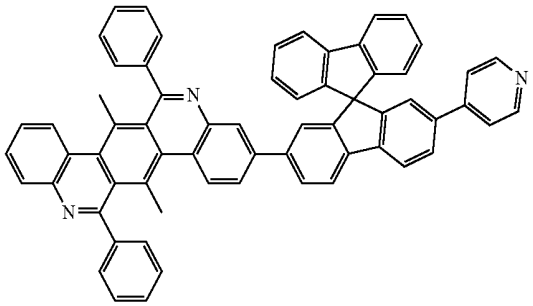

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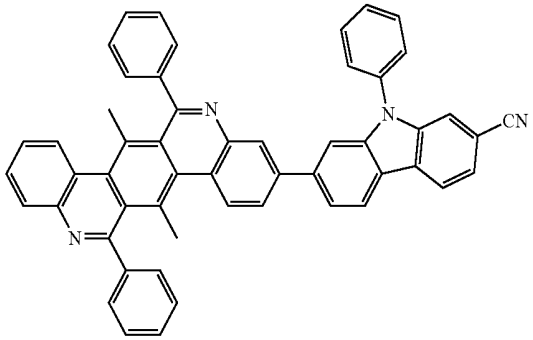

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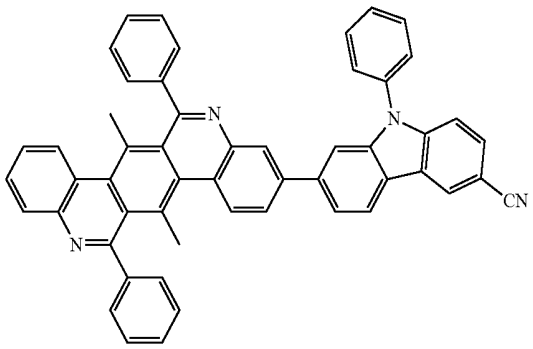

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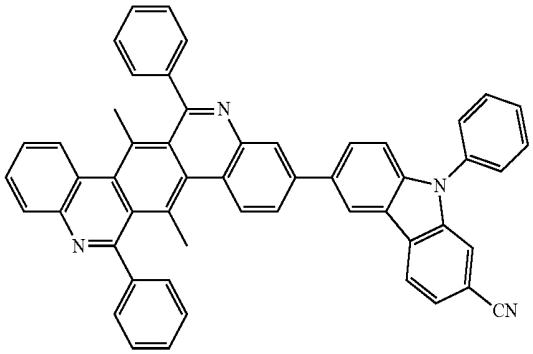

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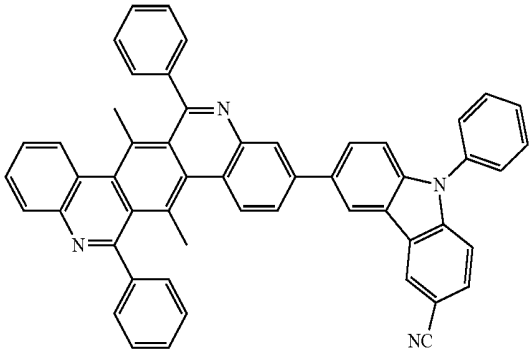

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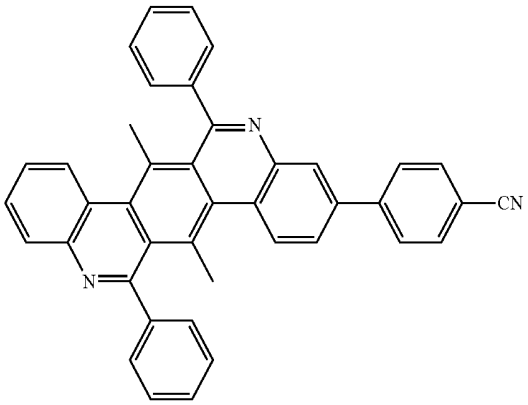

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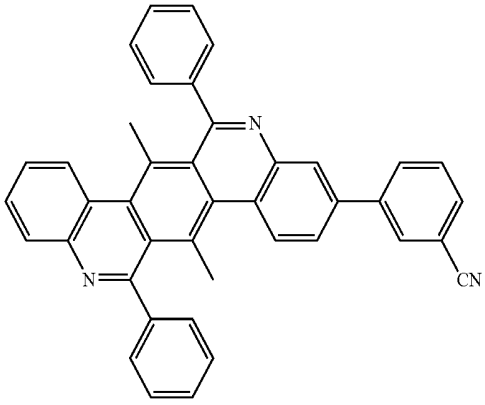

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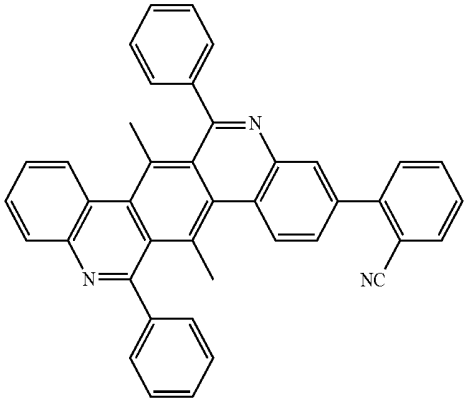

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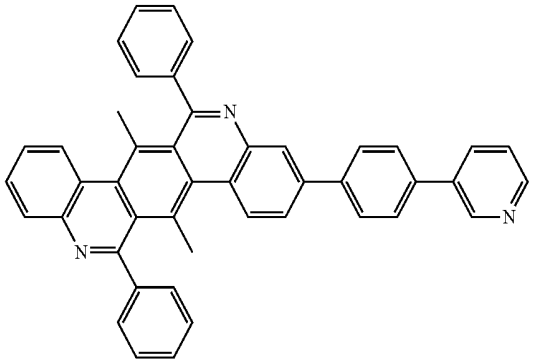

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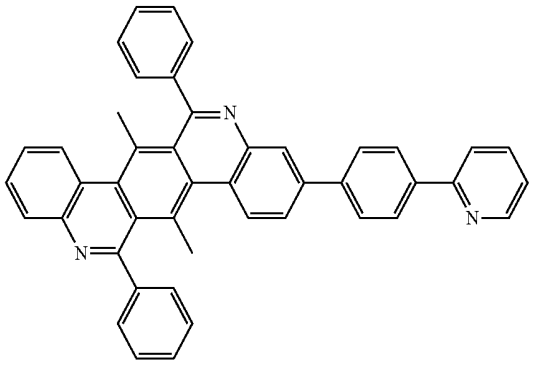

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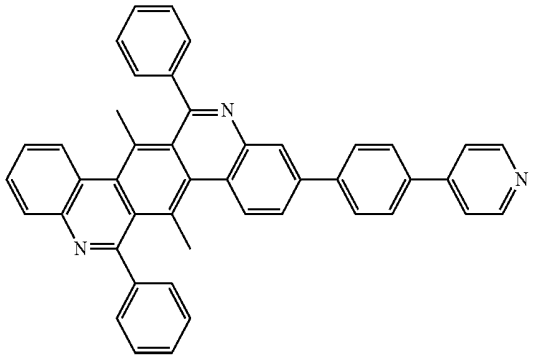

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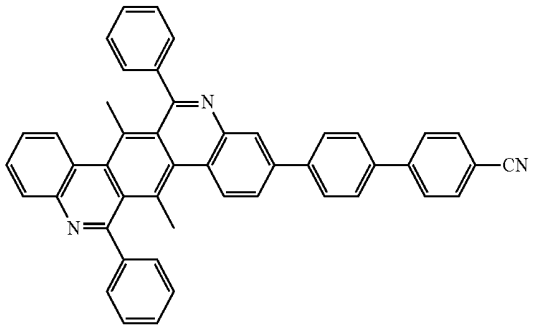

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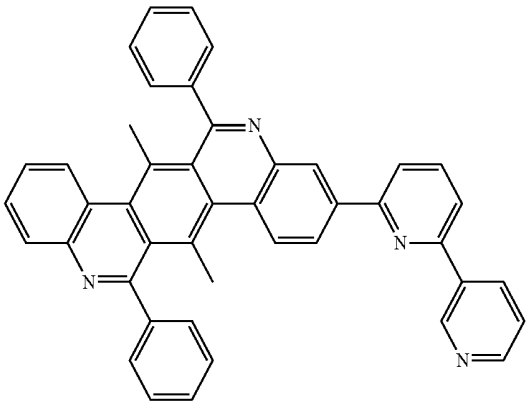

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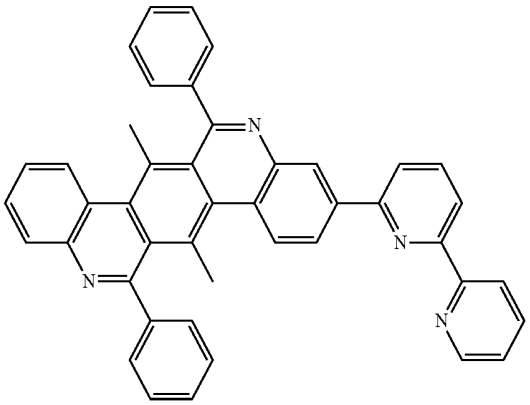

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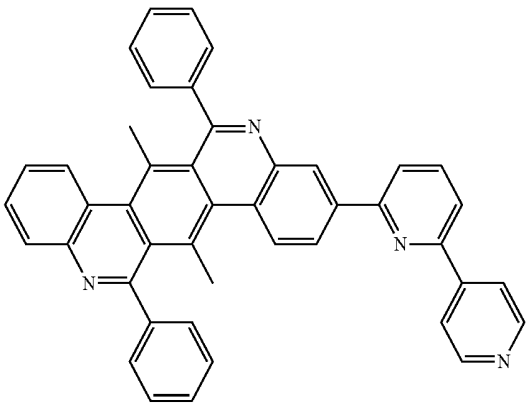

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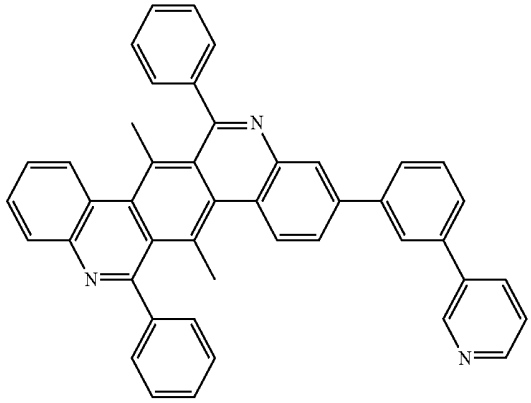

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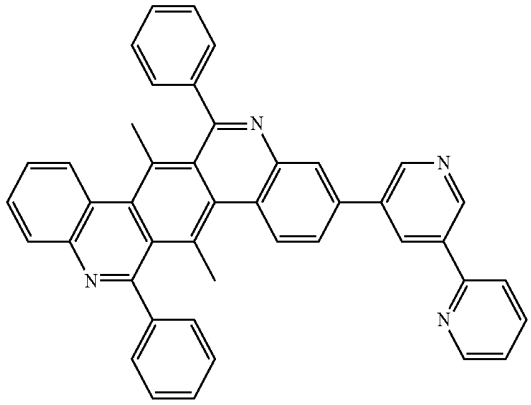

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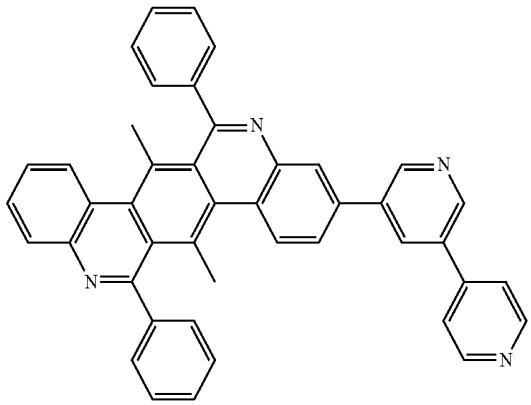

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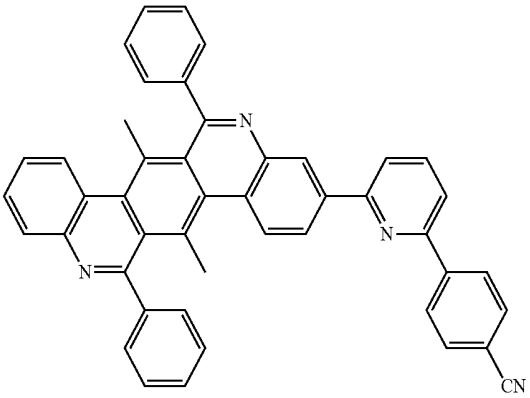

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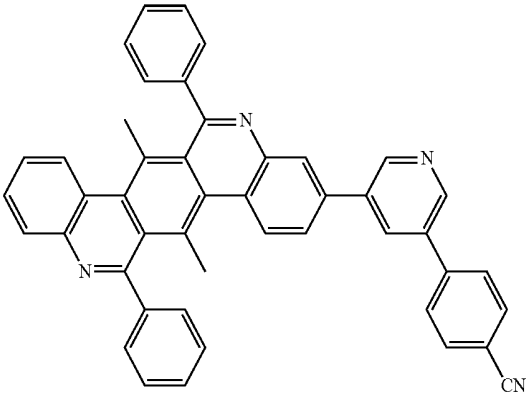

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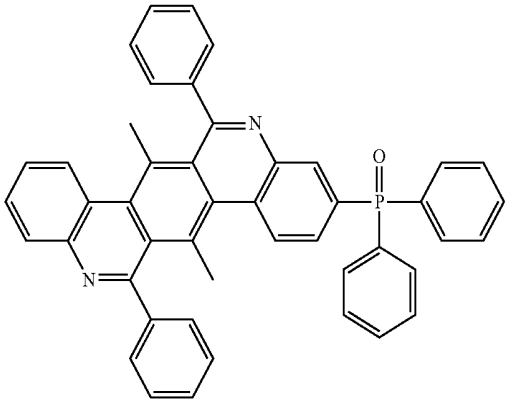

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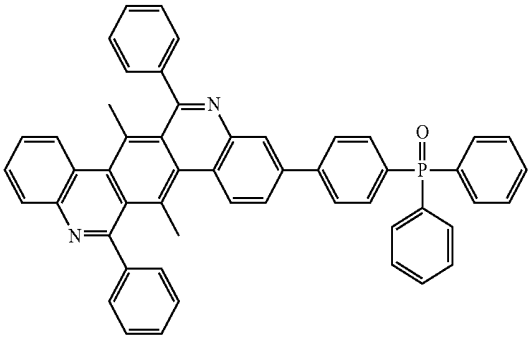

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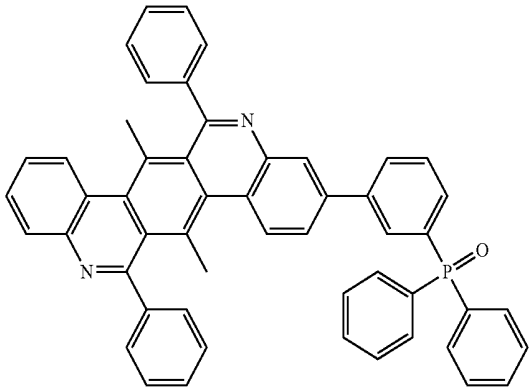

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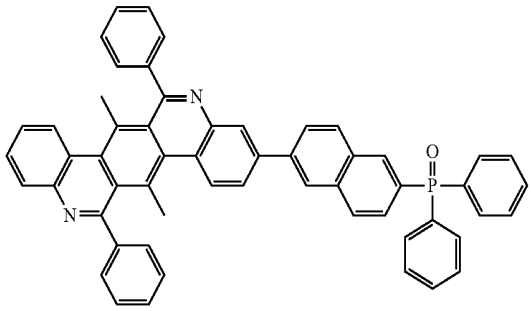

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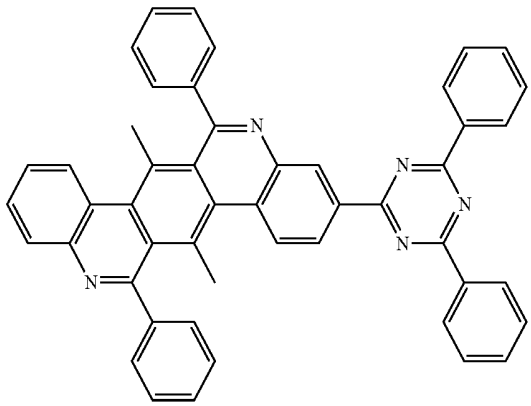

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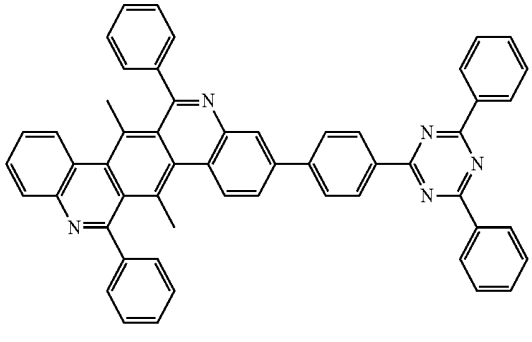

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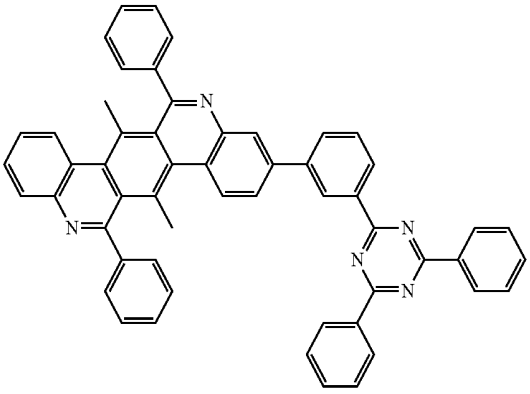

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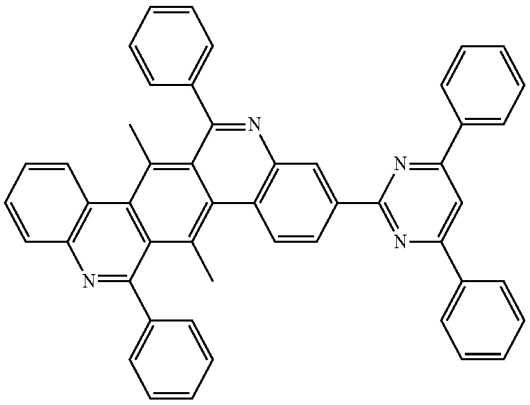

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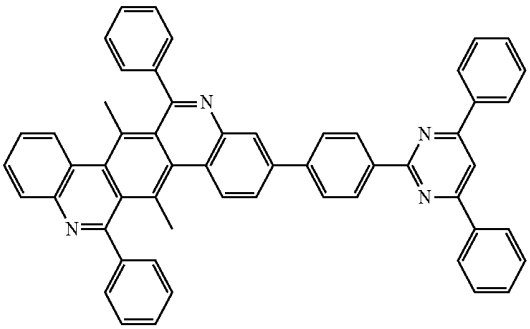

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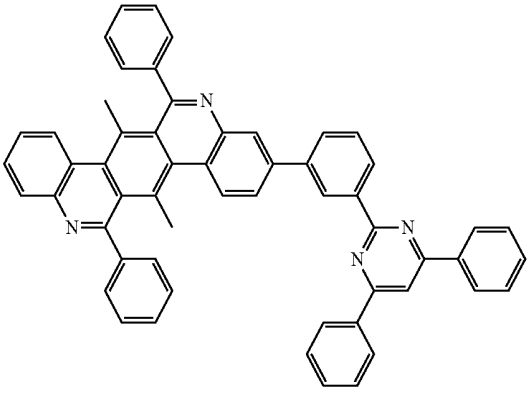

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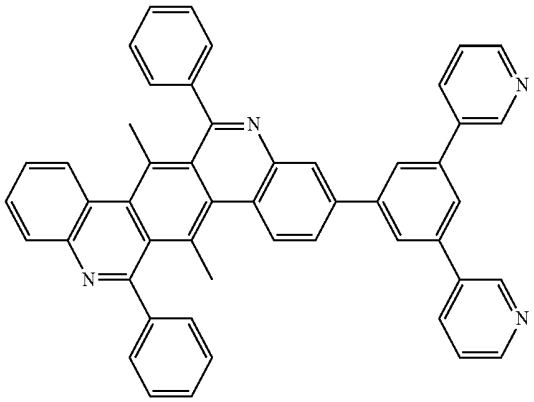

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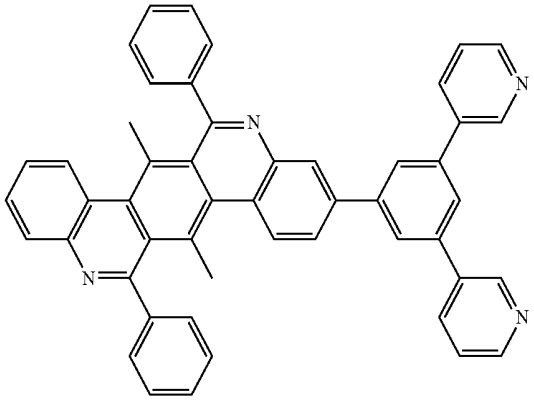

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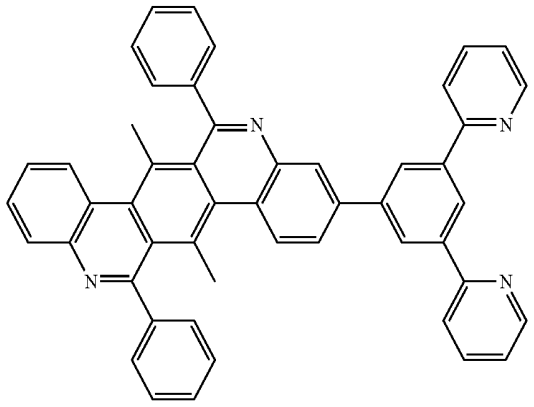

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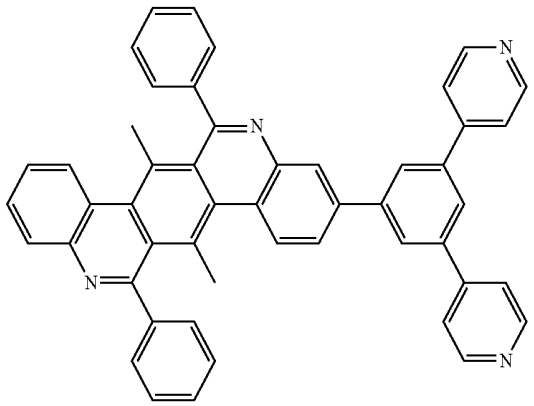

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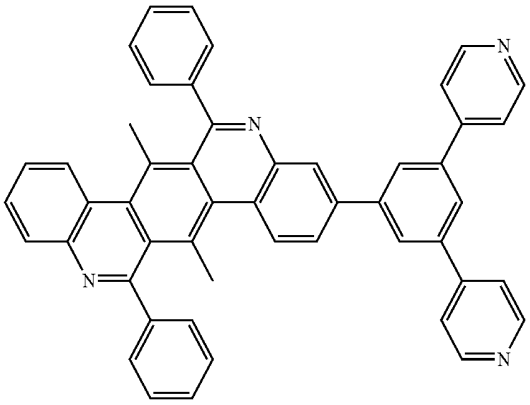

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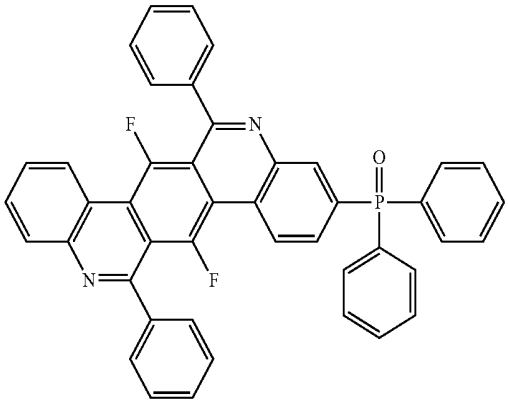

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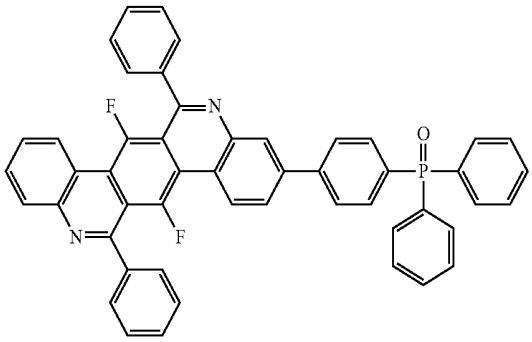

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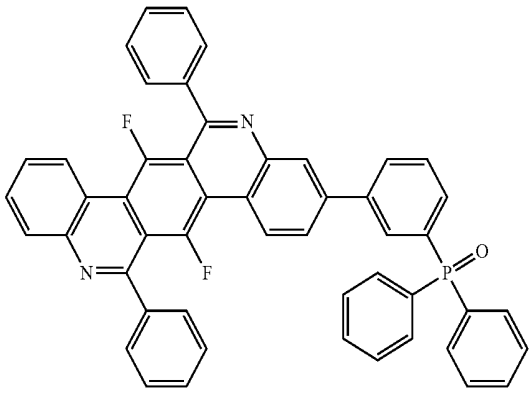

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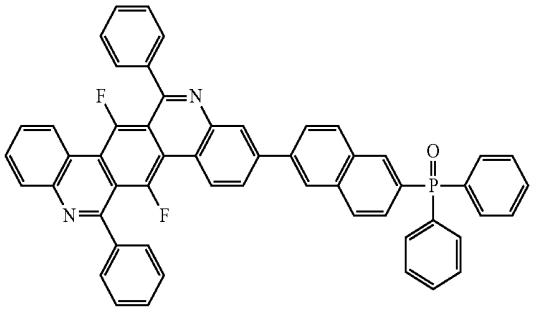
62



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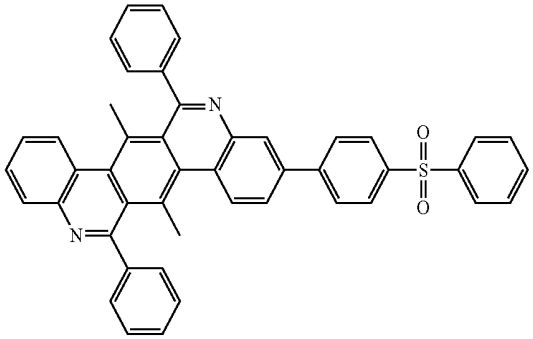

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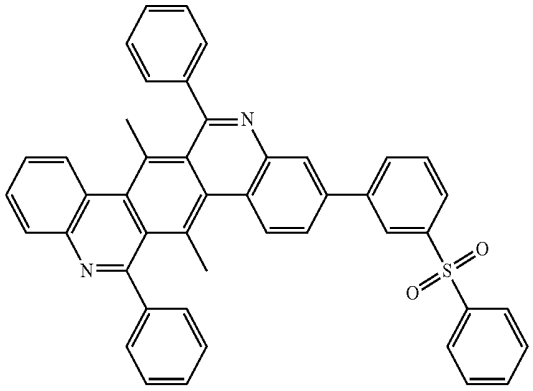

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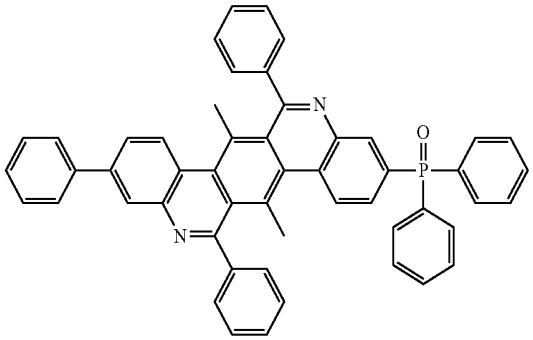

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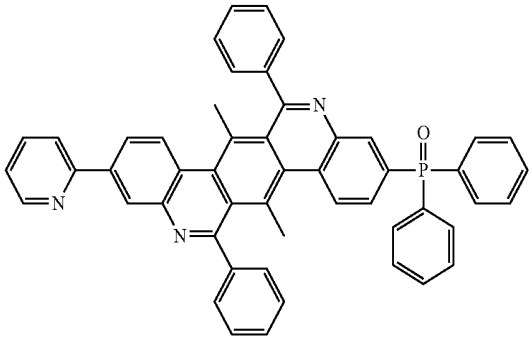

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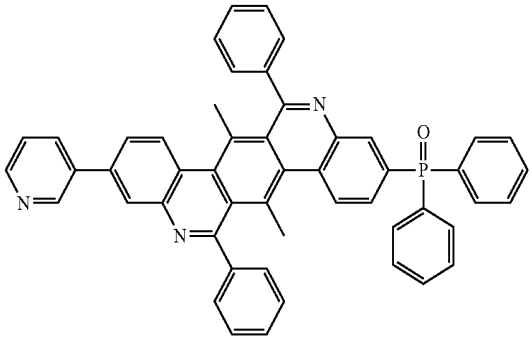

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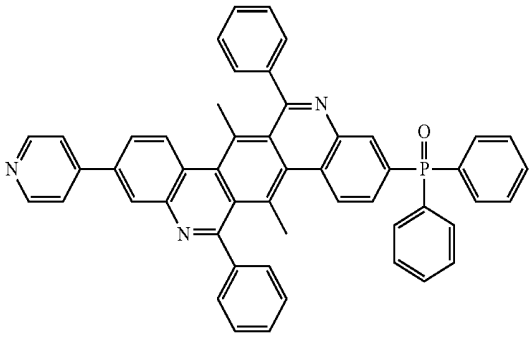

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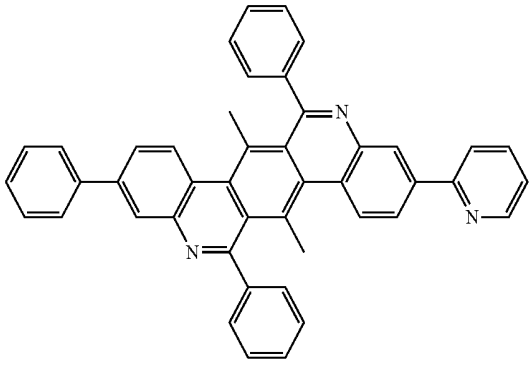

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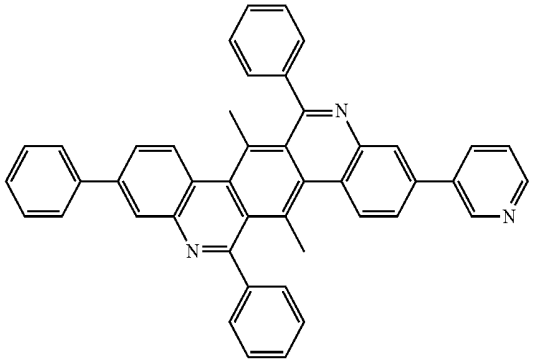

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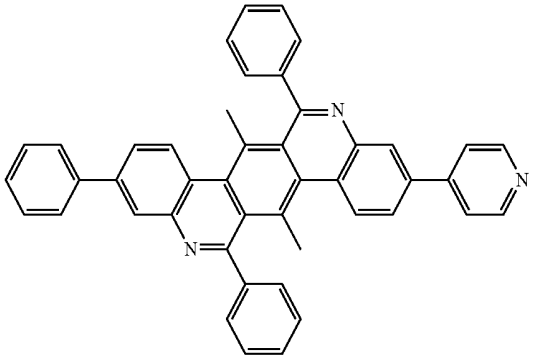

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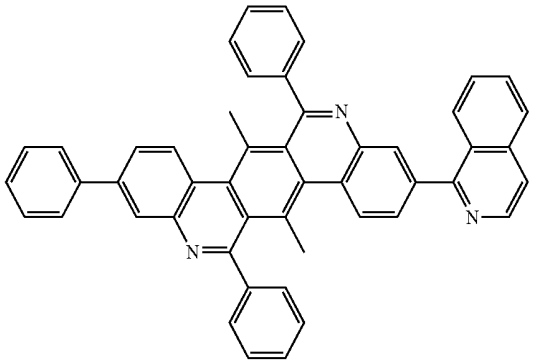

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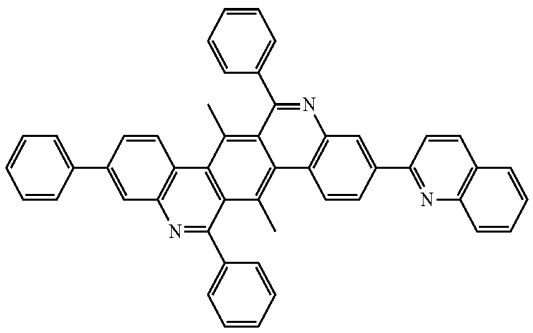

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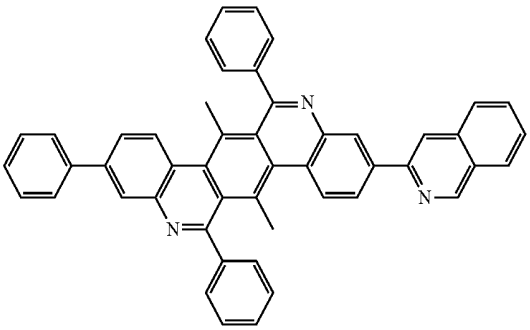

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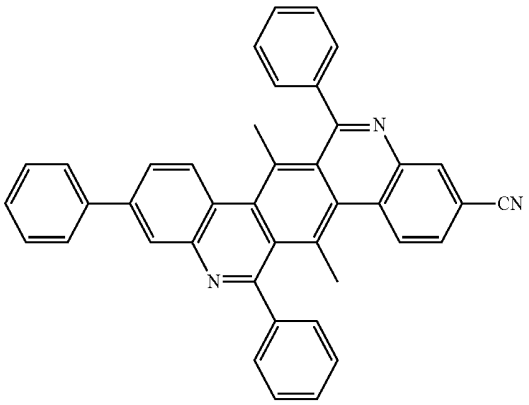

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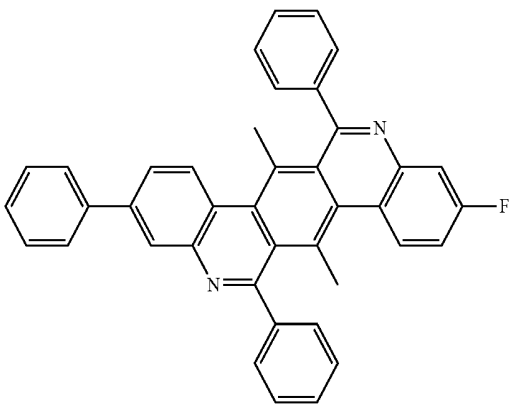

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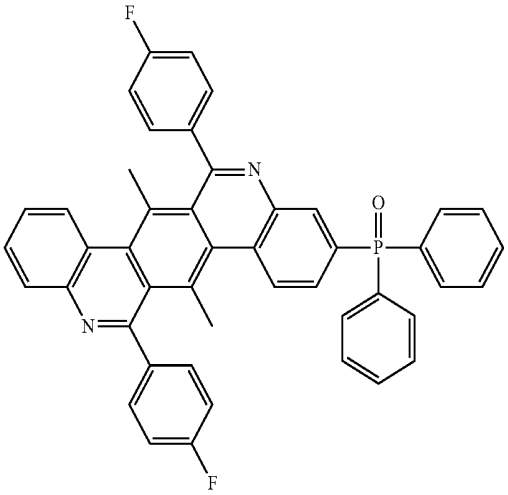

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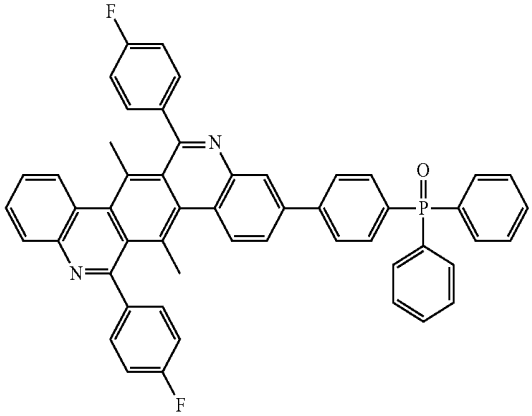

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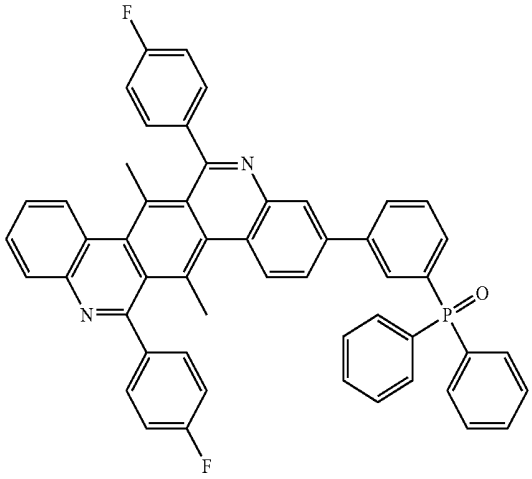

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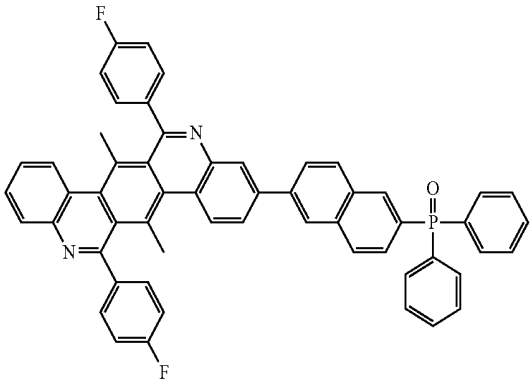

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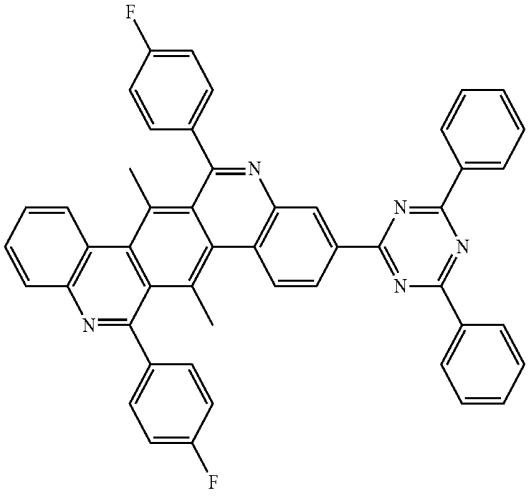

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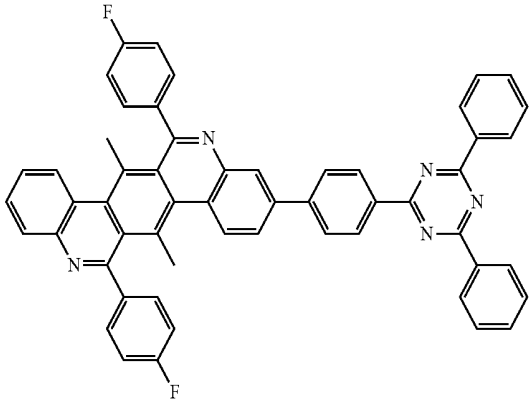

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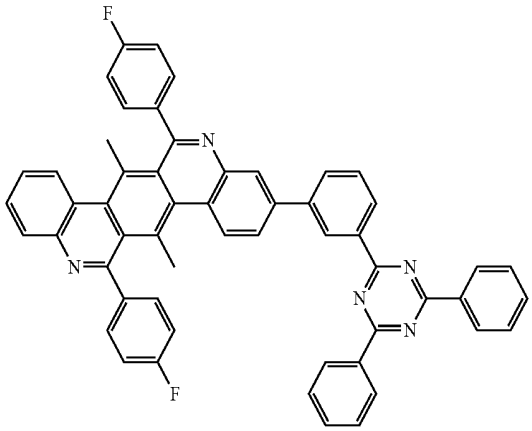

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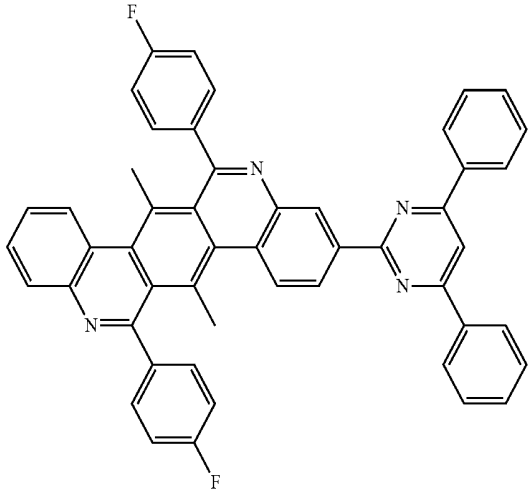

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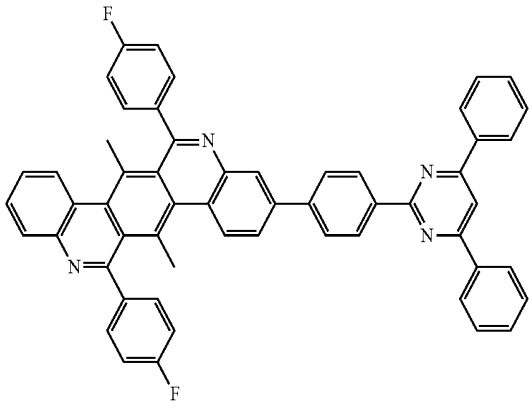

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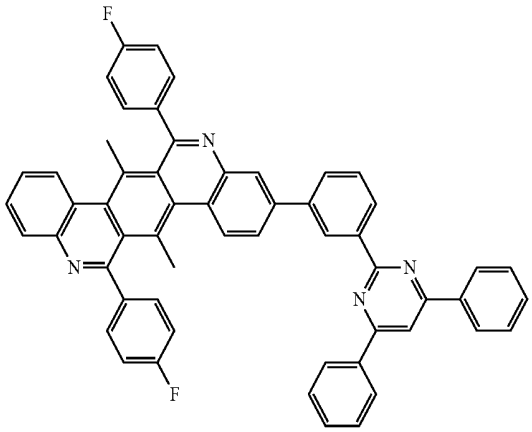

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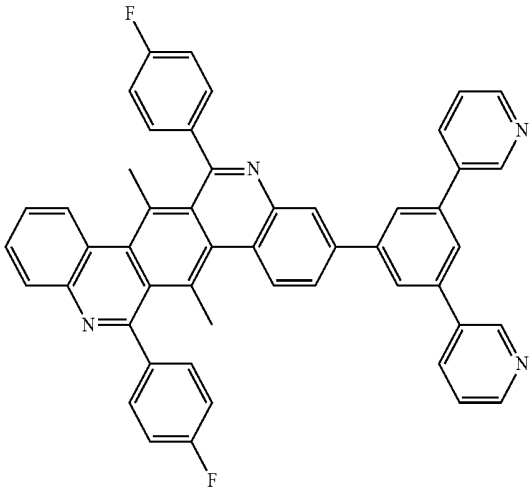

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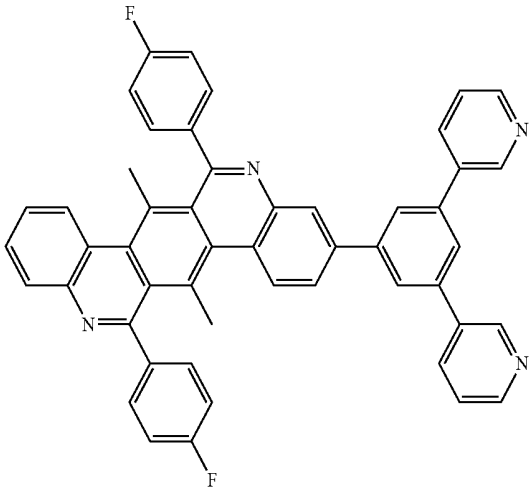

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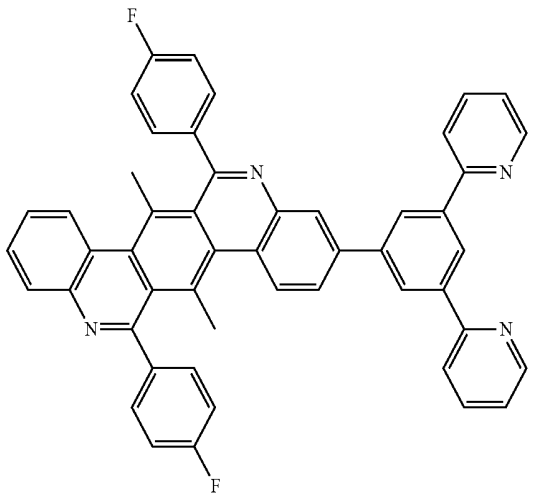

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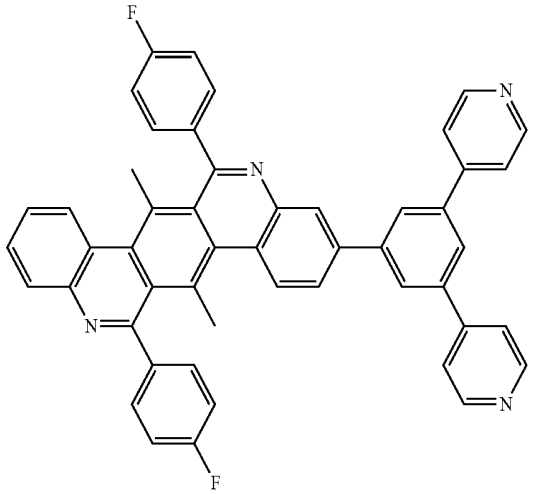

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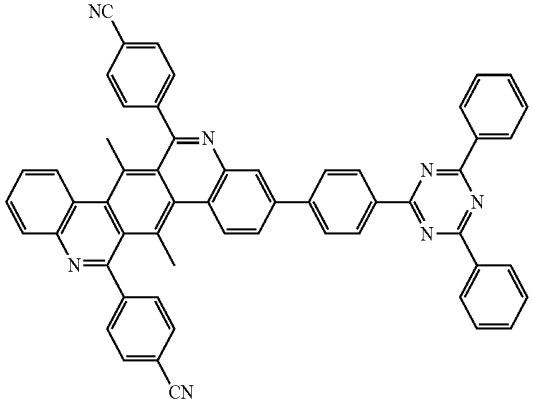

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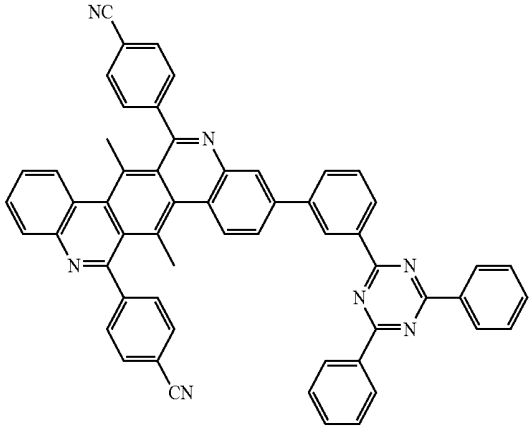

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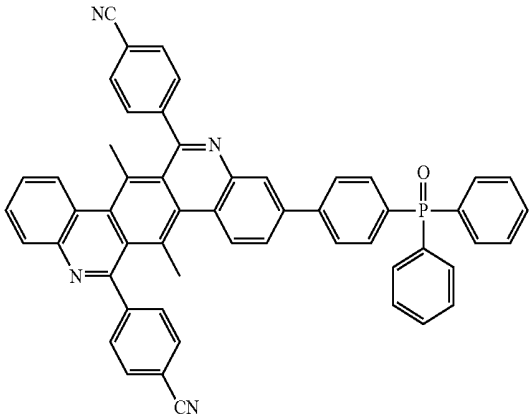

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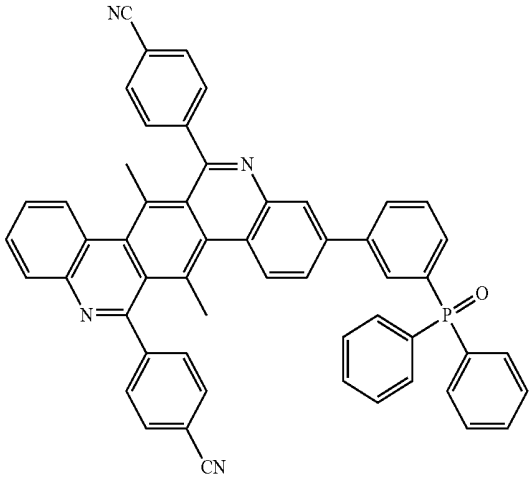

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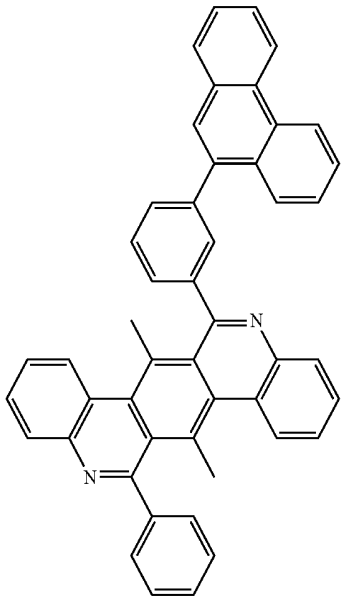

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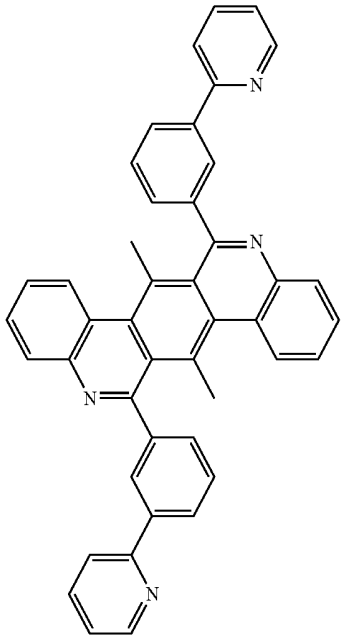

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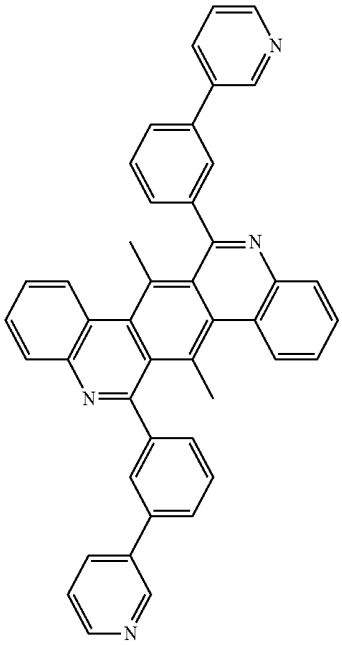

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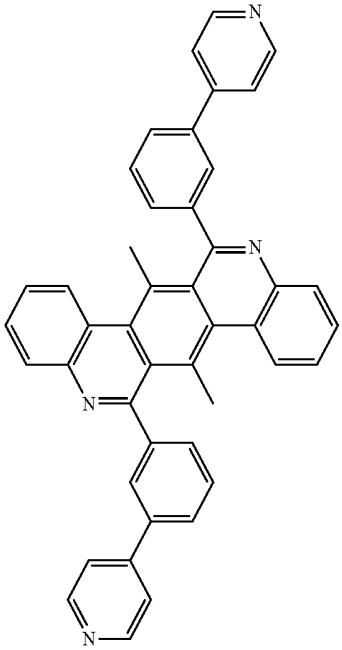

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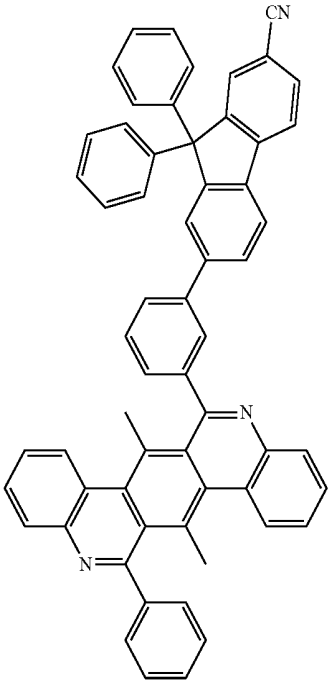

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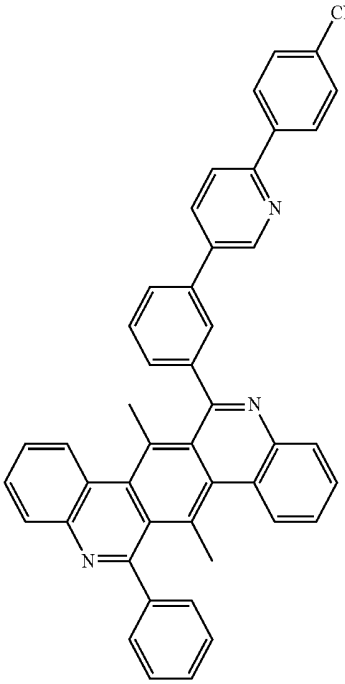

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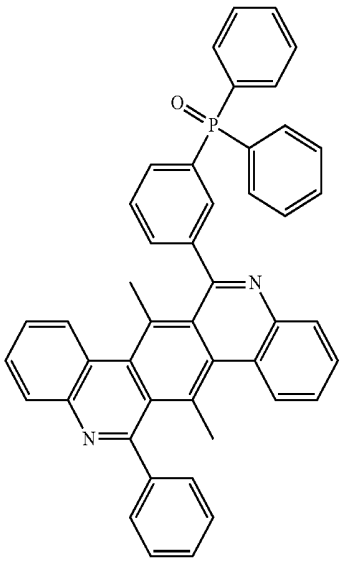

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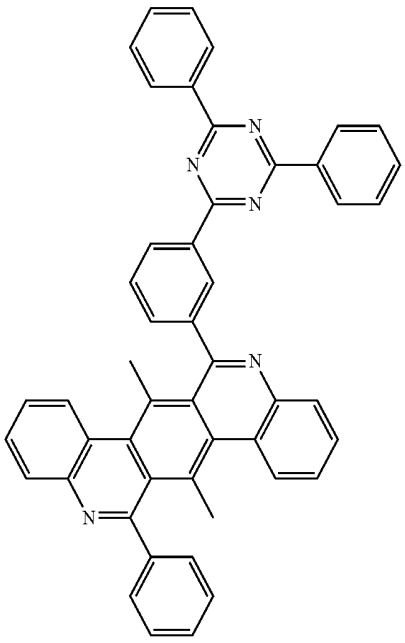

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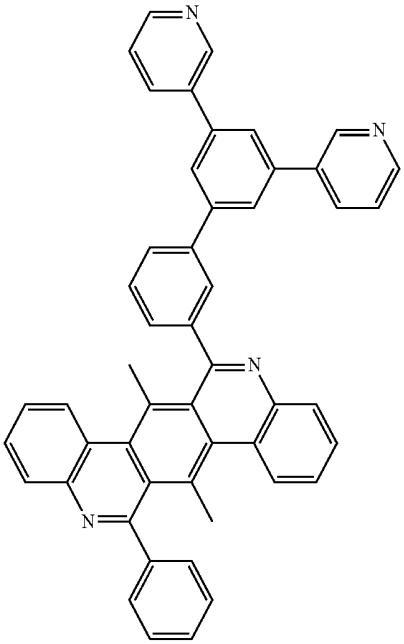

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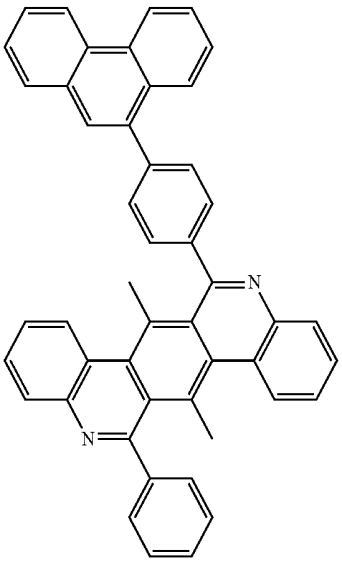

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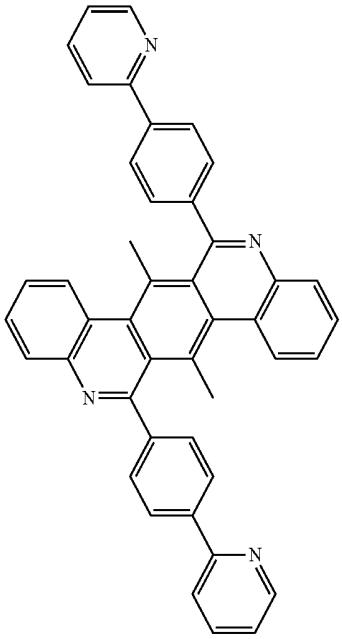

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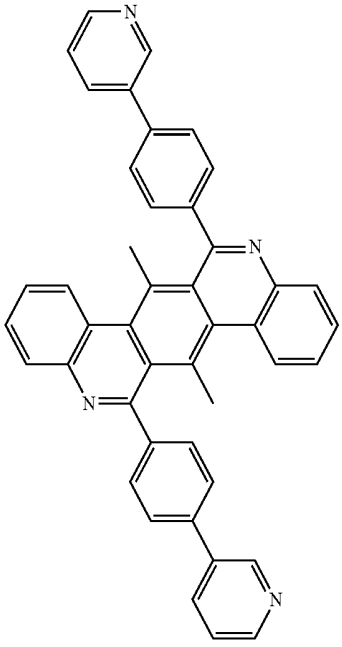

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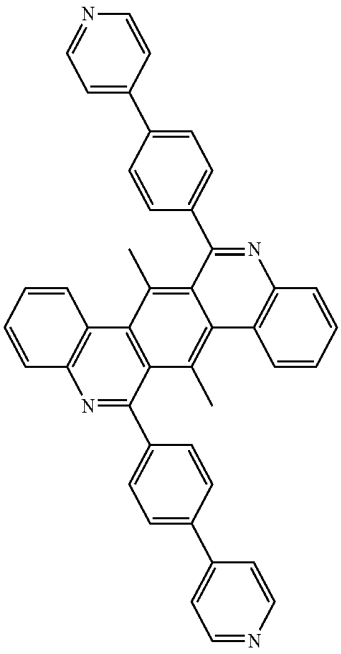

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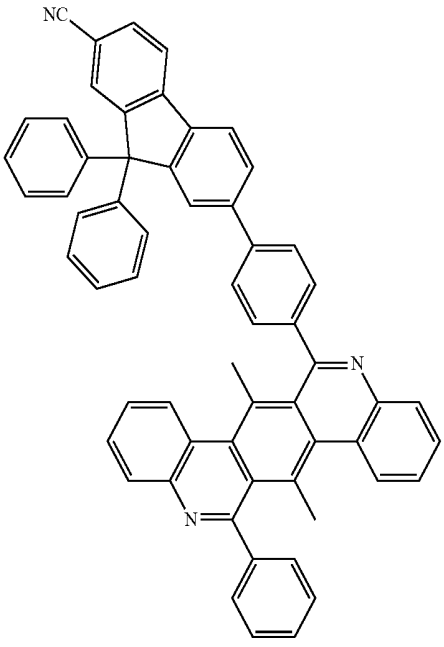

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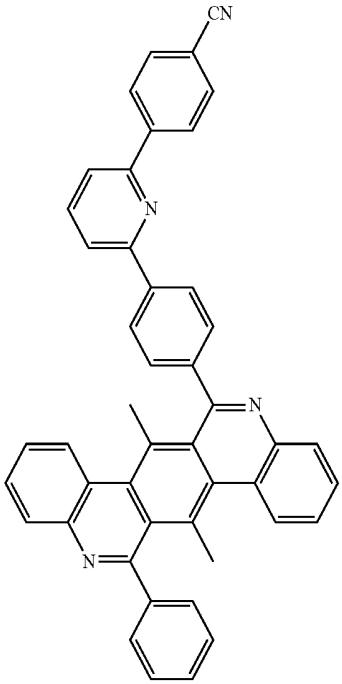

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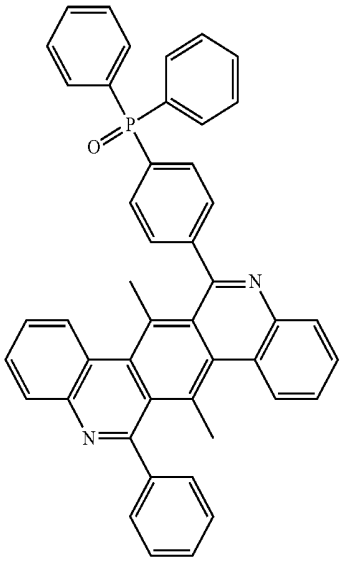

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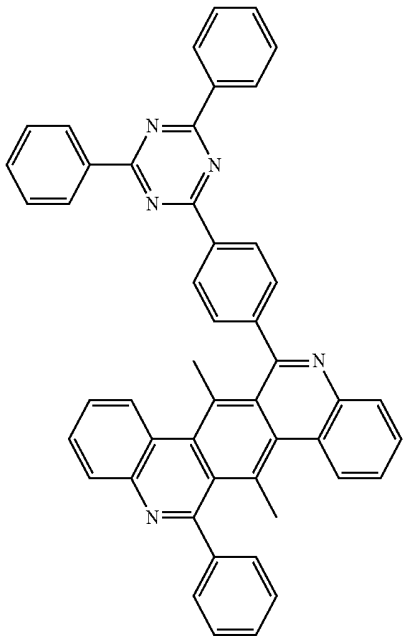

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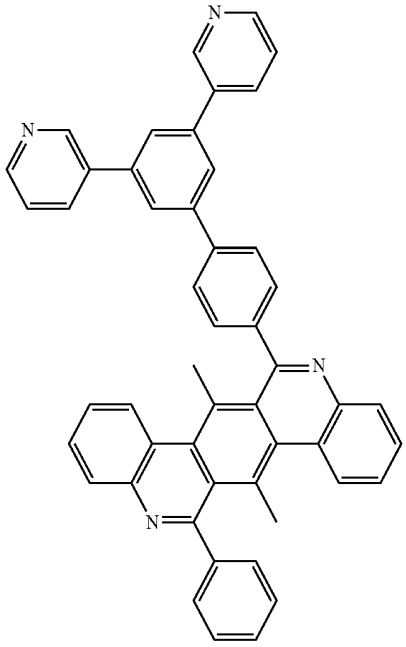

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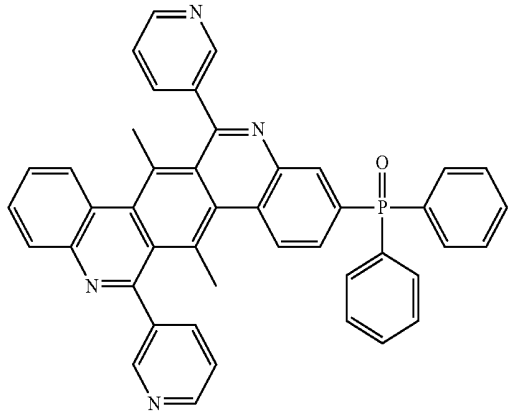

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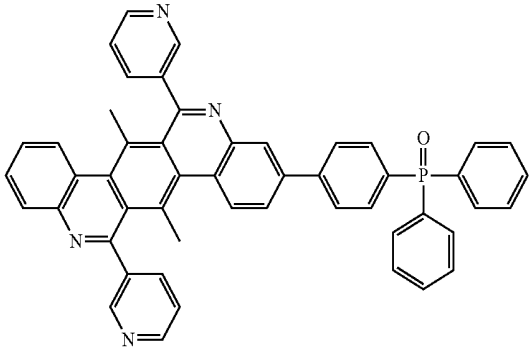

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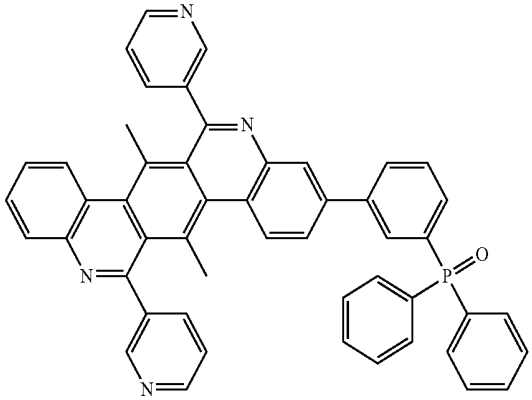

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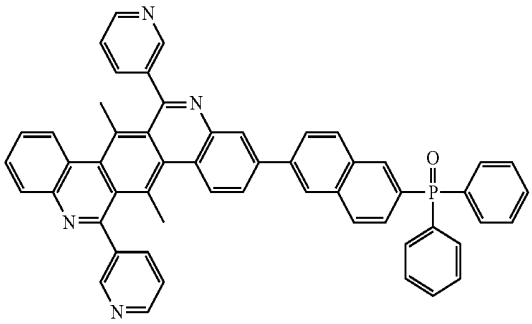

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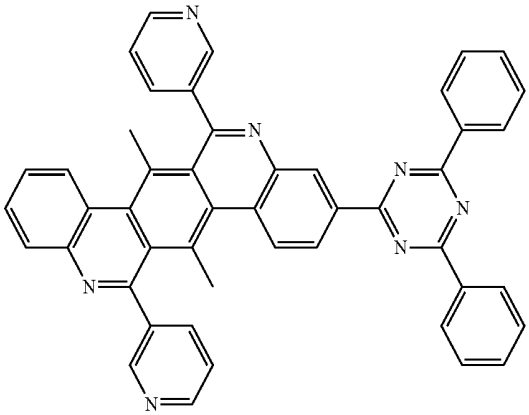

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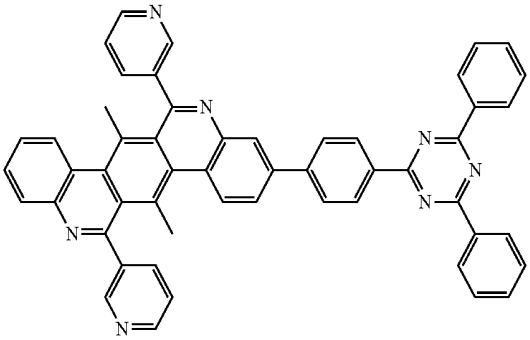

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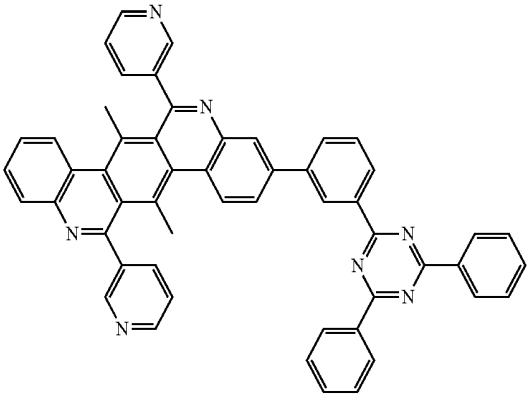

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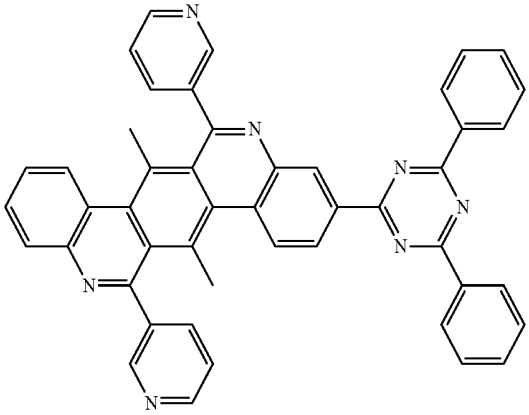

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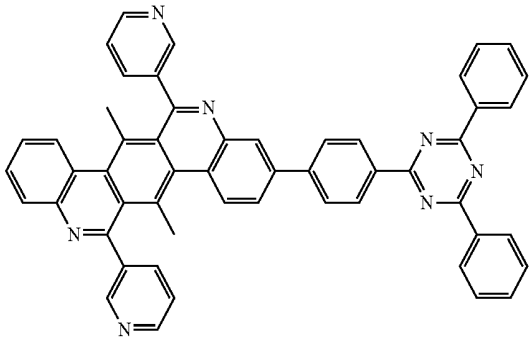

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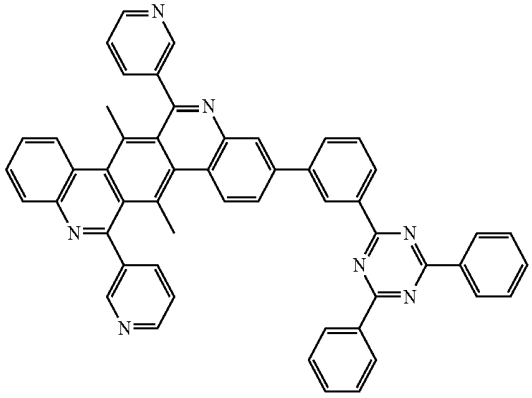

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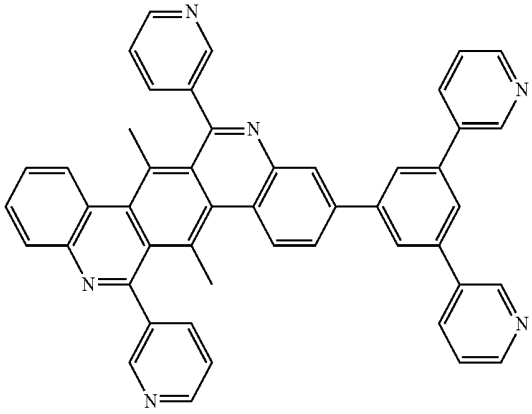

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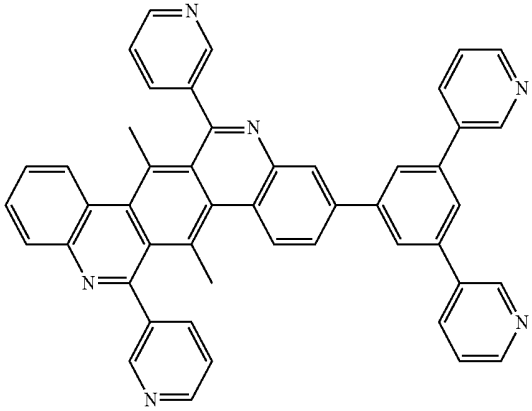

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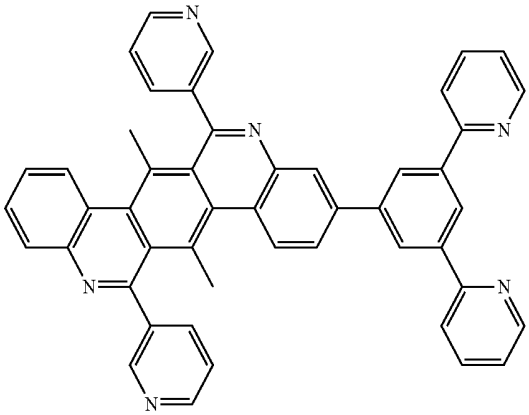

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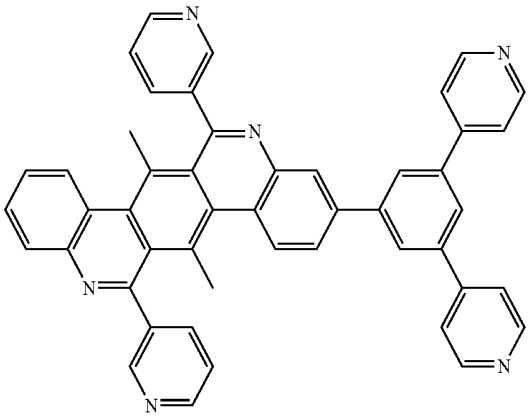

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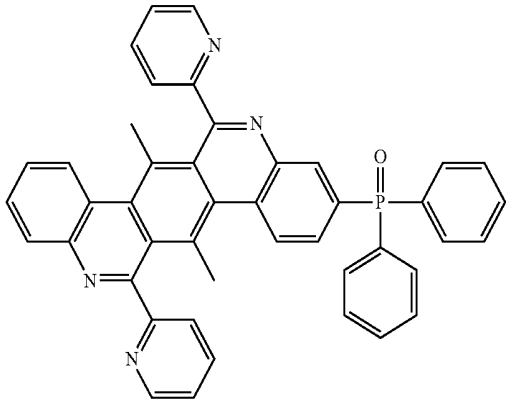

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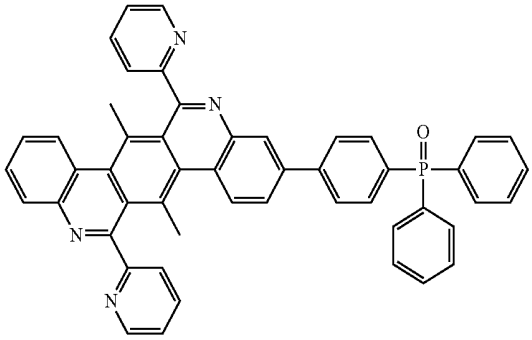

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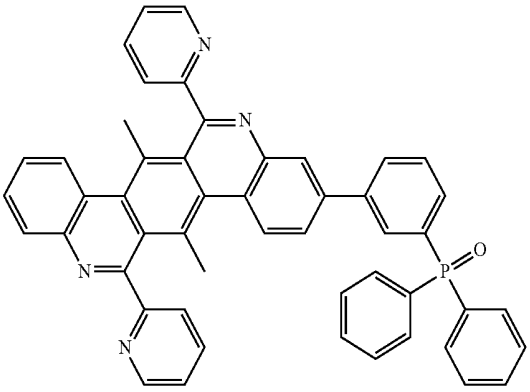

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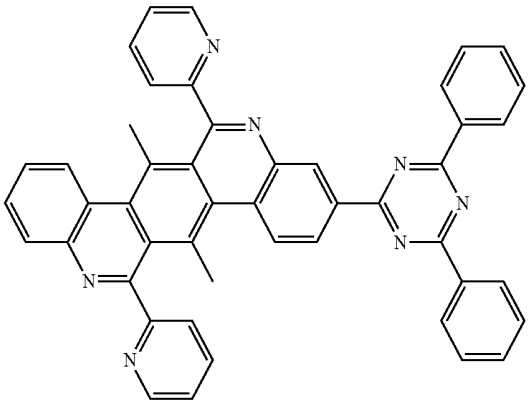

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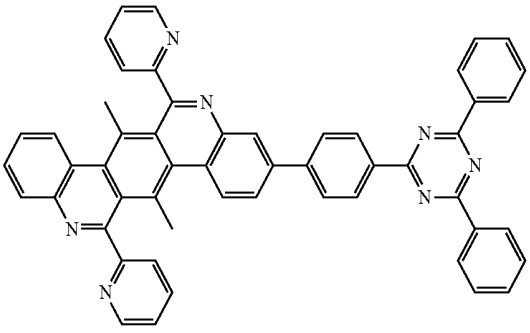

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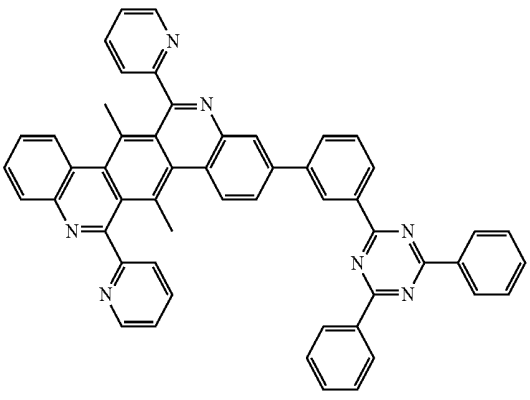

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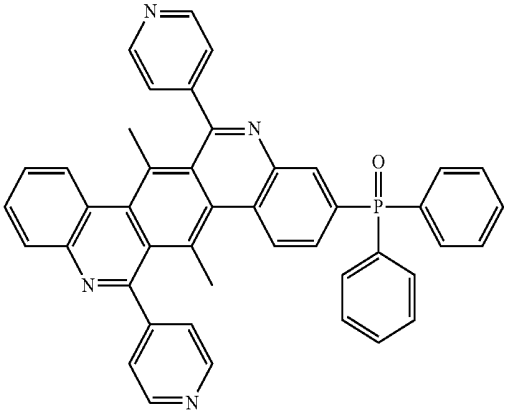

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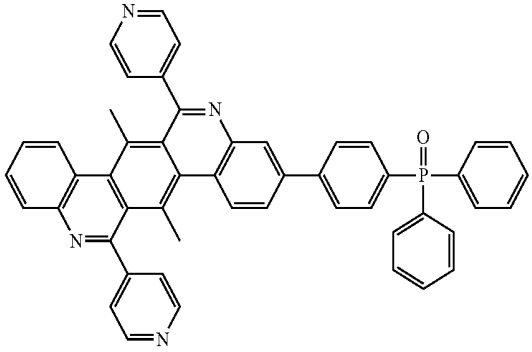

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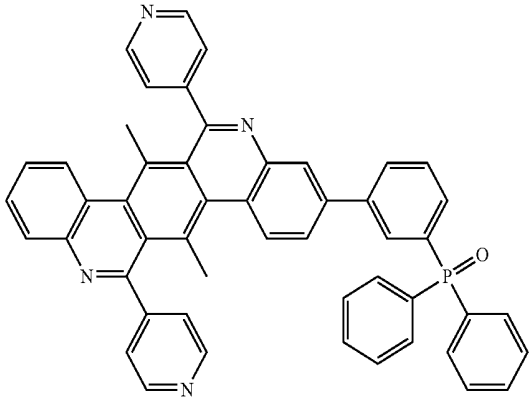

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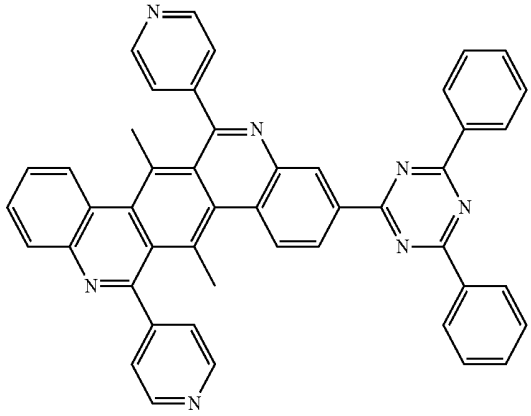

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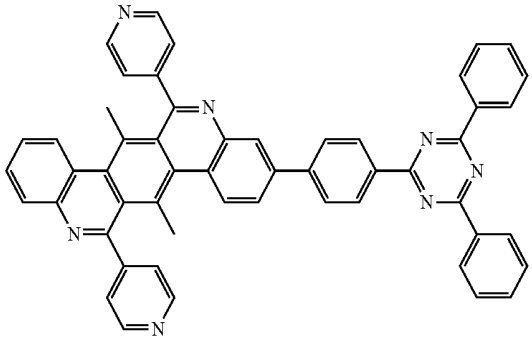

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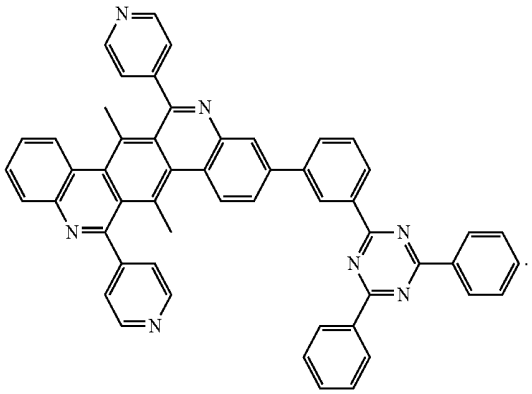


[0074] The condensed cyclic compound may have a structure of Formula 1 (including a group represented by Formula 2). For example, one or more substituents other than hydrogen may be included in the condensed cyclic compound, electron mobility may increase with an increase in a conjugation length, and heat resistance characteristics may be improved with an increase in a molecular weight.

[0075] In an implementation, the condensed cyclic compound may include two heteroatoms in a core and may have a planar structure, and it may be expected that an intermolecular interaction will increase such that electron injection and transport characteristics are improved.

[0076] A synthesis method for the condensed cyclic compound represented by Formula 1 may be apparent to those of ordinary skill in the art by referring to the following examples.

[0077] At least one condensed cyclic compound represented by Formula 1 may be used or included between a pair of electrodes constituting an organic light-emitting device. For example, the condensed cyclic compound may be included in at least one layer in a hole transport region, an electron transport region, or an emission layer. In an implementation, the condensed cyclic compound of Formula 1 may be used as a material for a capping layer located outside a pair of electrodes of an organic light-emitting device.

[0078] According to another aspect of embodiments, an organic light-emitting device may include: a first electrode, a second electrode, and an organic layer between the first electrode and the second electrode, the organic layer including an emission layer and at least one heterocyclic compound represented by Formula 1 described above.

[0079] The expression "(an organic layer) includes at least one condensed cyclic compound" used herein may include a case in which "(an organic layer) includes identical compounds represented by Formula 1" and a case in which "(an organic layer) includes two or more different condensed cyclic compounds."

[0080] In an implementation, the first electrode is an anode, and the second electrode is a cathode, and the organic layer further a hole transport region between the first electrode and the emission layer and an electron transport region between the emission layer and the second electrode, and the hole transport region includes a hole injection layer, a hole transport layer, an emission auxiliary layer, an electron blocking layer, or any combination thereof, and the electron transport region includes a buffer layer, a hole blocking layer, an electron control layer, an electron transport layer, an electron injection layer, or any combination thereof.

[0081] In an implementation, the electron transport region may include at least one condensed cyclic compound described above.

[0082] The emission layer may include a host, and the host of the emission layer may include at least one selected from an anthracene-based compound, a pyrene-based compound, and a spiro-bifluorene-based compound.

[0083] The emission layer may include a dopant, and the dopant of the emission layer may include at least one selected from a styryl-based compound and an amine-based compound.

[0084] In an implementation, the emission layer of the organic light-emitting device may be a first emission layer for emitting first color light.

[0085] In an implementation, the organic light-emitting device may include i) at least one second emission layer for emitting second color light or ii) at least one second emission layer for emitting second color light and at least one third emission layer for emitting third color light, between the first electrode and the second electrode.

[0086] In an implementation, a maximum emission wavelength of the second emission layer for emitting first color light, a maximum emission wavelength of the second emission layer for emitting second color light, and a maximum emission wavelength of the third emission layer for emitting third color light are identical to or different from each other.

[0087] In an implementation, the first color light and the second color light are emitted in the form of mixed light, or the first color light, the second color light, and the third color light are emitted in the form of mixed light.

[0088] In an implementation, the organic light-emitting device may further include at least one selected from a first capping layer disposed in a pathway along which light generated in an emission layer proceeds toward the outside through the first electrode and a second capping layer disposed in a pathway along which light generated in an emission layer proceeds toward the outside through the second electrode, and the at least one selected from the first capping layer and the second capping layer may include at least one condensed cyclic compound represented by Formula 1.

[0089] In an implementation, the organic light-emitting device may have i) a stack structure including a first electrode, an organic layer, a second electrode, and a second capping layer which are sequentially stacked in this stated order, ii) a stack structure including a first capping layer, a first electrode, an organic layer, and a second electrode which are sequentially stacked in this stated order, or iii) a stack structure including a first capping layer, a first elec-

trode, an organic layer, a second electrode, and a second capping layer which are sequentially stacked in this stated order, and at least one selected from the first capping layer and the second capping layer may include the condensed cyclic compound.

[0090] 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.

[0091] [Description of FIGS. **1** and **2**]

[0092] FIG. **1** illustrates a schematic view of an organic light-emitting device **10** according to an embodiment. The organic light-emitting device **10** may include a first electrode **110**, an organic layer **150**, and a second electrode **190**.

[0093] FIG. **2** illustrates a schematic view of an organic light-emitting device **20** according to an embodiment. The organic light-emitting device **20** may include the first electrode **110**, the organic layer **150** including a hole transport region **150***a*, an emission layer **150***b*, and an electron transport region **150***c*, and a second electrode **190**.

[0094] Hereinafter, the structure of each of the organic light-emitting devices **10** and **20** according to embodiments and a method of manufacturing the same will be described in connection with FIGS. **1** and **2**.

[0095] [First Electrode **110**]

[0096] Referring to FIGS. **1** to **2**, a substrate may be additionally disposed under the first electrode **110** or above the second electrode **190**. The substrate may be a glass substrate or a plastic substrate, each having excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and water resistance.

[0097] 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 a first electrode may be selected from materials with a high work function to facilitate hole injection.

[0098] 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 a first electrode may be selected from indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO_2), zinc oxide (ZnO), and any combinations thereof. In an implementation, when the first electrode **110** is a semi-transmissive electrode or a reflectable electrode, a material for forming a first electrode may be selected from magnesium (Mg), silver (Ag), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), magnesium-silver (Mg—Ag), and any combinations thereof.

[0099] The first electrode **110** may have a single-layered structure, or a multi-layered structure including two or more layers. For example, the first electrode **110** may have a three-layered structure of ITO/Ag/ITO.

[0100] [Organic Layer **150**]

[0101] The organic layer **150** is disposed on the first electrode **110**. The organic layer **150** may include the emission layer **150***b*.

[0102] The organic layer **150** may further include the hole transport region **150***a* between the first electrode **110** and the emission layer **150***b*, and the electron transport region **150***c* between the emission layer **150***b* and the second electrode **190**.

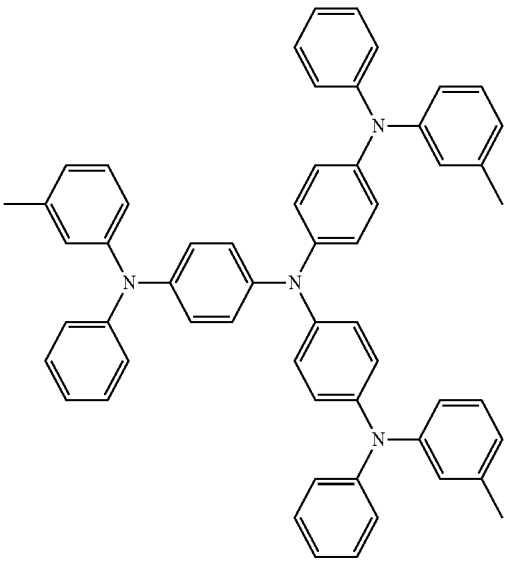
[0103] [Hole Transport Region **150***a* in Organic Layer **150**]

[0104] The hole transport region **150***a* may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

[0105] The hole transport region **150***a* may include at least one layer selected from a hole injection layer (HIL), a hole transport layer (HTL), an emission auxiliary layer, and an electron blocking layer (EBL).

[0106] For example, the hole transport region **150***a* may have a single-layered structure including a single layer including a plurality of different materials, or a multi-layered structure having a hole injection layer/hole transport layer structure, a hole injection layer/hole transport layer/emission auxiliary layer structure, a hole injection layer/emission auxiliary layer structure, a hole transport layer/emission auxiliary layer structure, or a hole injection layer/hole transport layer/electron blocking layer structure, wherein for each structure, constituting layers are sequentially stacked from the first electrode **110** in this stated order.

[0107] The hole transport region **150***a* may include at least one selected from m-MTDATA, TDATA, 2-TNATA, NPB (NPD), P3-NPB, TPD, Spiro-TPD, Spiro-NPB, methylated-NPB, TAPC, HMTPD, 4,4',4"-tris(N-carbazolyl)triphenylamine (TCTA), polyaniline/dodecylbenzenesulfonic acid (PANI/DBSA), poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate) (PEDOT/PSS), polyaniline/camphor sulfonic acid (PANI/CSA), polyaniline/poly(4-styrenesulfonate) (PANI/PSS), a compound represented by Formula 201, and a compound represented by Formula 202:



m-MTDATA

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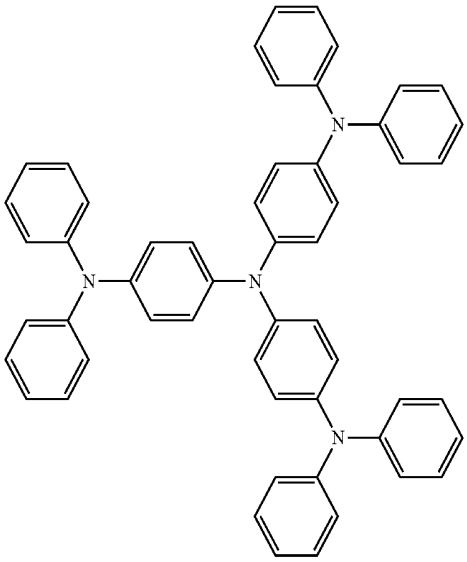
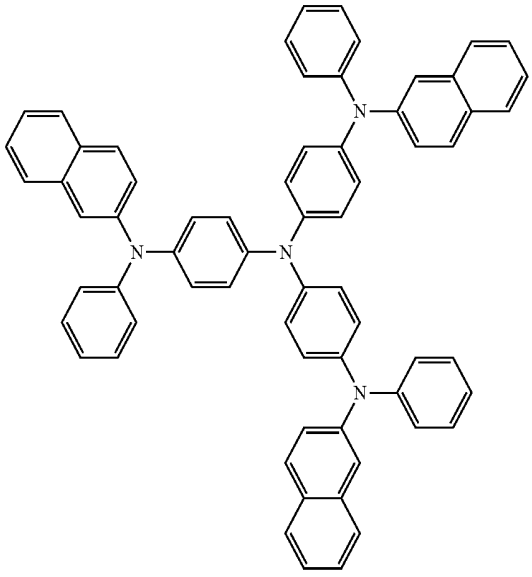
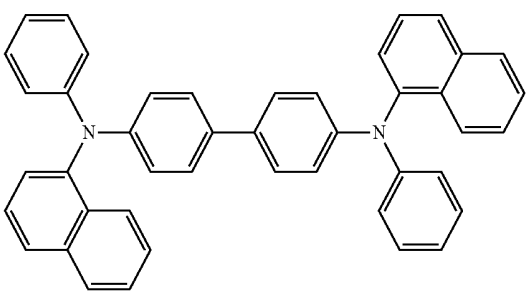


TDATA



2-TNATA



NPB

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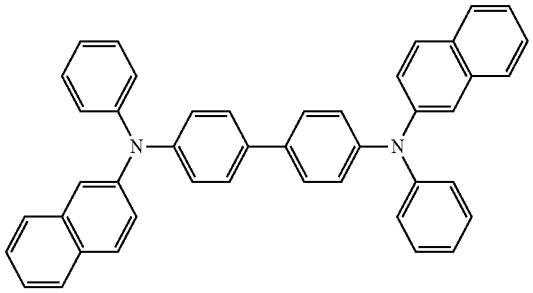
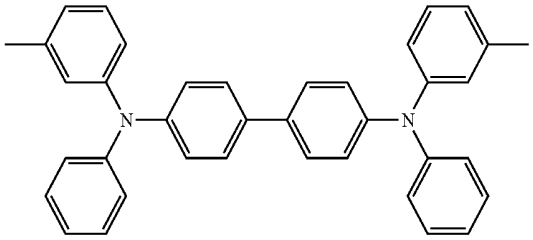
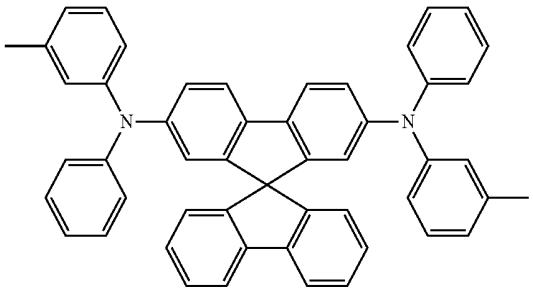


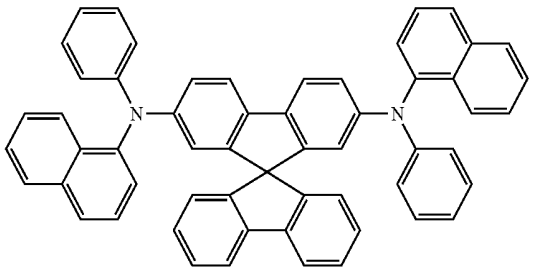
β-NPB



TPD



Spiro-TPD



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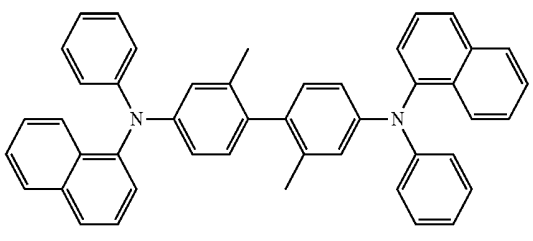

methylated NPB

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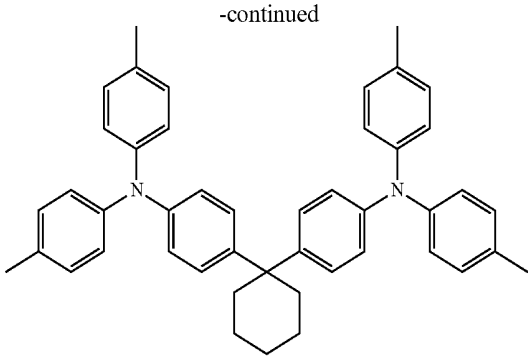
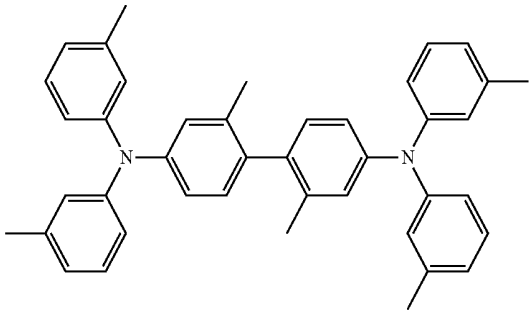
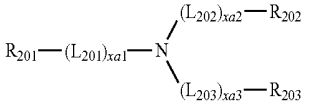


TAPC

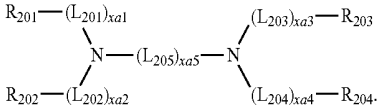


HMTPD

<Formula 201>



<Formula 202>



[0108] In Formulae 201 and 202,

[0109] L_{201} to L_{204} may each independently be selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3-C_{10} cycloalkenylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6-C_{60} arylene group, a substituted or unsubstituted C_1-C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0110] 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, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0111] xa1 to xa4 may each independently be an integer from 0 to 3,

[0112] xa5 may be an integer from 1 to 10,

[0113] R_{201} to R_{204} and Q_{201} may each independently be selected from a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group.

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

[0115] In one or more embodiments, in Formulae 201 and 202,

[0116] L_{201} to L_{205} may each independently be selected from:

[0117] 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;

[0118] 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, —$Si(Q_{31})(Q_{32})(Q_{33})$, and —$N(Q_{31})(Q_{32})$; and

[0119] Q_{31} to Q_{33} may each independently be selected from a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0120] In one or more embodiments, xa1 to xa4 may each independently be 0, 1, or 2.

[0121] In one or more embodiments, xa5 may be 1, 2, 3, or 4.

[0122] In one or more embodiments, R_{201} to R_{204} and Q_{201} may each independently be selected from:

[0123] 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;

[0124] 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, —$Si(Q_{31})(Q_{32})(Q_{33})$, and —$N(Q_{31})(Q_{32})$; and

[0125] Q_{31} to Q_{33} may be the same as described above.

[0126] In one or more embodiments, at least one selected from R_{201} to R_{203} in Formula 201 may each independently be selected from:

[0127] a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

[0128] 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, and a dibenzothiophenyl group.

[0129] In one or more embodiments, in Formula 202, i) R_{201} and R_{202} may be linked via a single bond, and/or ii) R_{203} and R_{204} may be linked via a single bond.

[0130] In one or more embodiments, at least one selected from R_{201} to R_{204} in Formula 202 may be selected from:

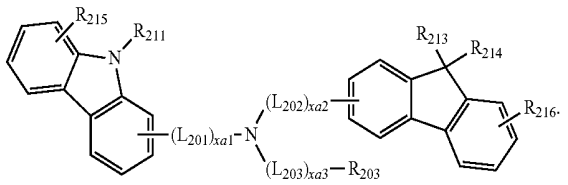
[0131] a carbazolyl group; and

[0132] 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 cyclo-

hexenyl 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, and a dibenzothiophenyl group.

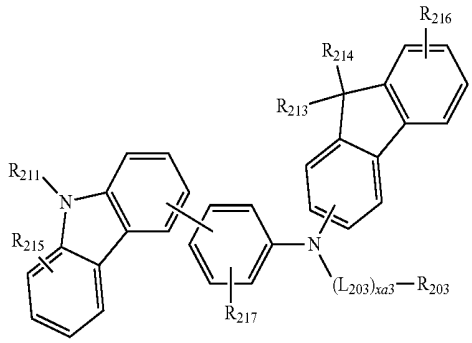
[0133] The compound represented by Formula 201 may be represented by Formula 201A:

<Formula 201A>



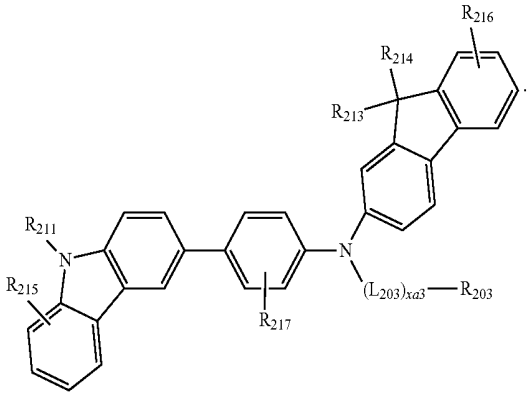
[0134] In an implementation, the compound represented by Formula 201 may be represented by Formula 201A(1) below:

<Formula 201A(1)>



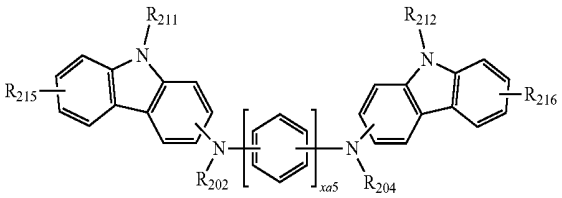
[0135] In an implementation, the compound represented by Formula 201 may be represented by Formula 201A-1:

<Formula 201A-1>



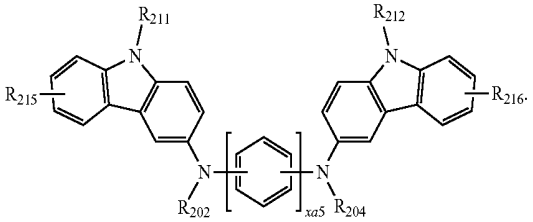
[0136] In an implementation, the compound represented by Formula 202 may be represented by Formula 202A:

<Formula 202A>



[0137] In an implementation, the compound represented by Formula 202 may be represented by Formula 202A-1:

<Formula 202A-1>



[0138] In Formulae 201A, 201A(1), 201A-1, 202A, and 202A-1,

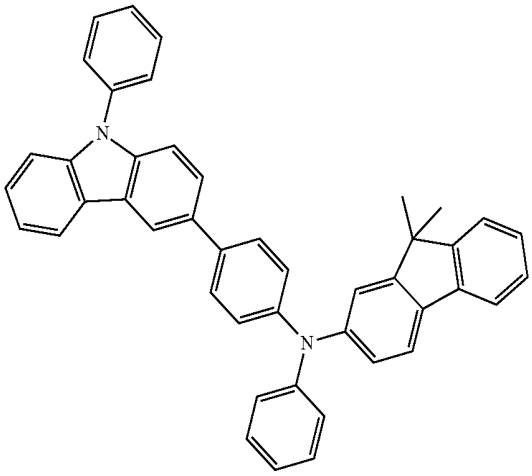
[0139] L_{201} to L_{203}, xa1 to xa3, xa5, and R_{202} to R_{204} are the same as described above,

[0140] R_{211} and R_{212} may be understood by referring to the description provided herein in connection with R_{203}.

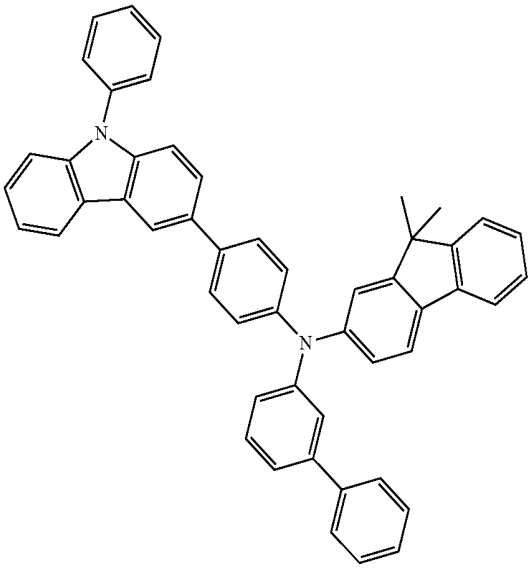
[0141] R_{213} to R_{217} may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1-C_{10} alkyl group, a phenyl group substituted with —F, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group.

[0142] In an implementation, the hole transport region **150***a* may include at least one compound selected from Compounds HT1 to HT39:

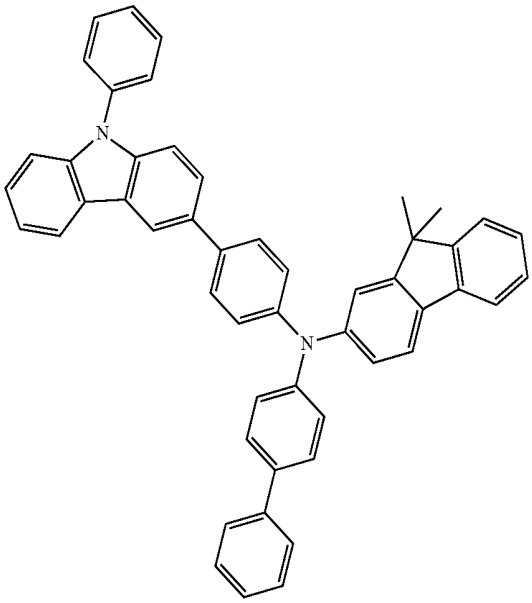
HT1



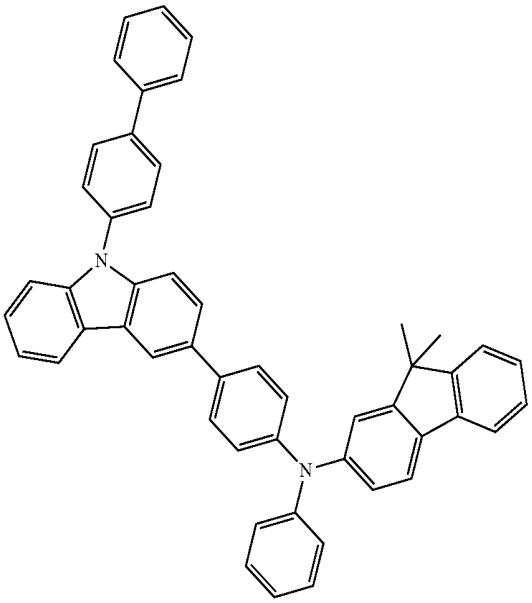
HT2



HT3



HT4



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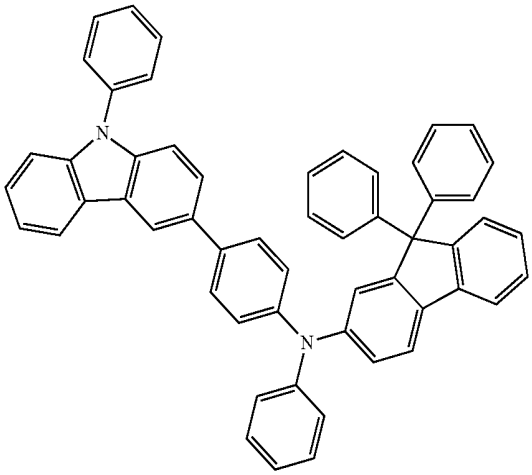
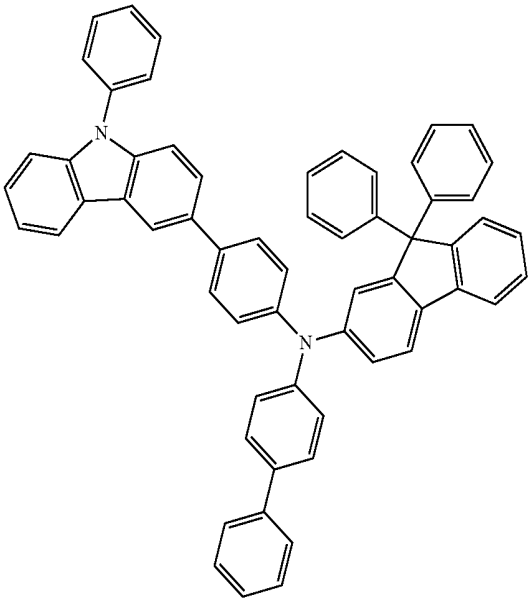
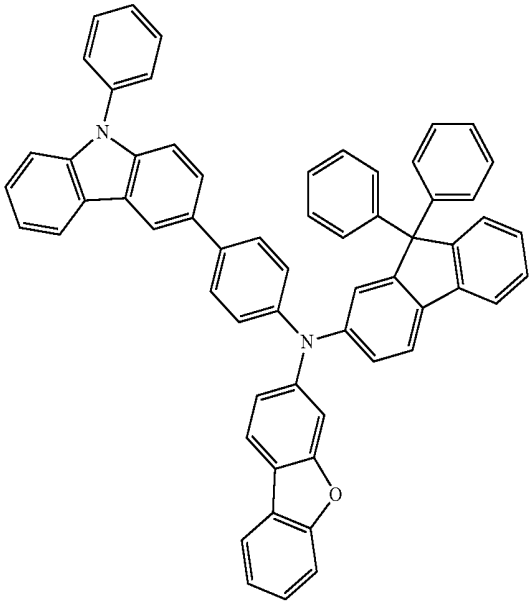
HT5



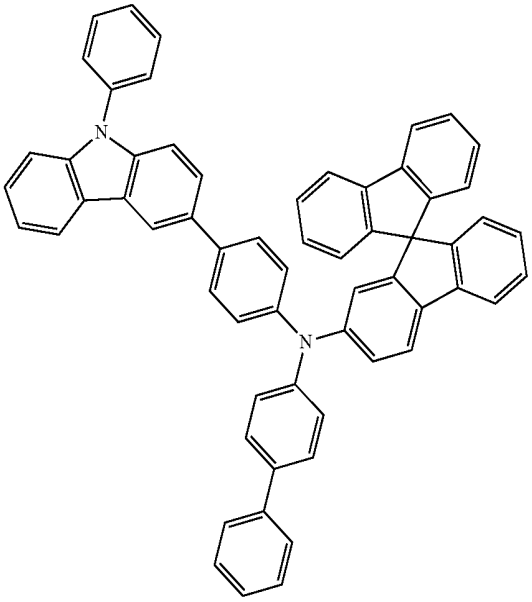
HT6



HT7



HT8



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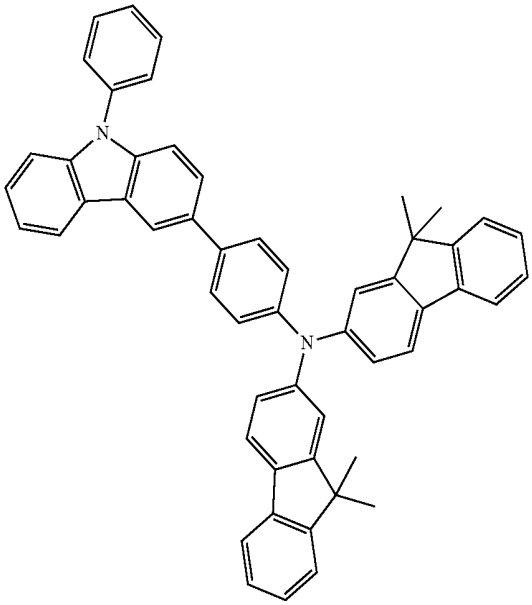
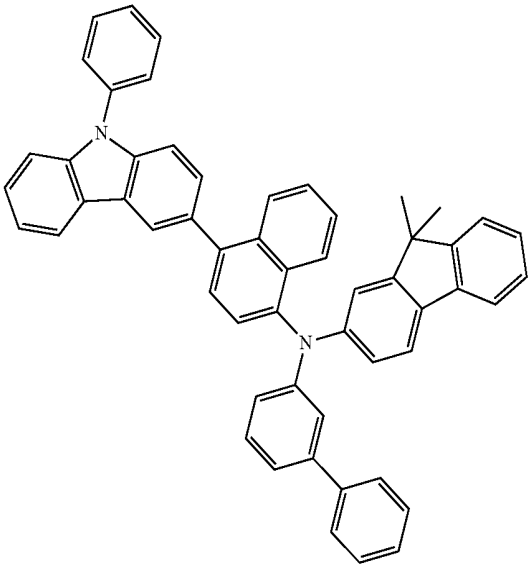
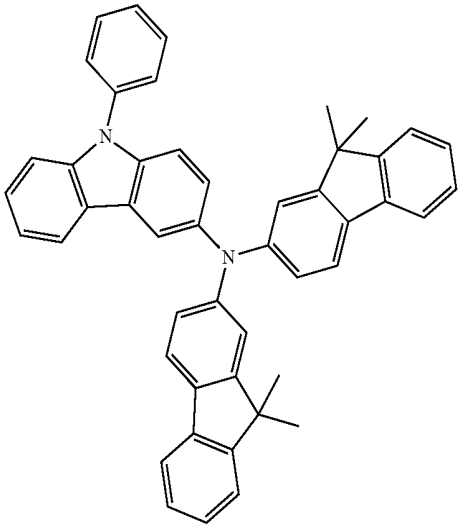
HT9



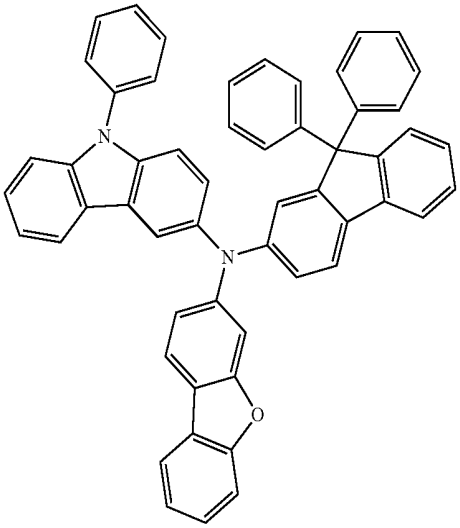
HT10



HT11



HT12



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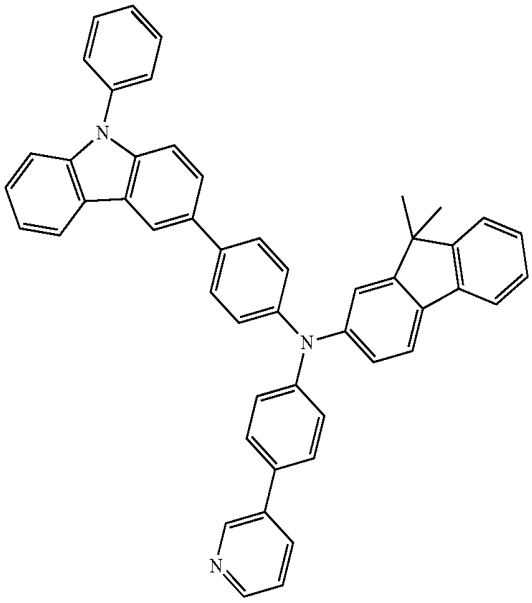
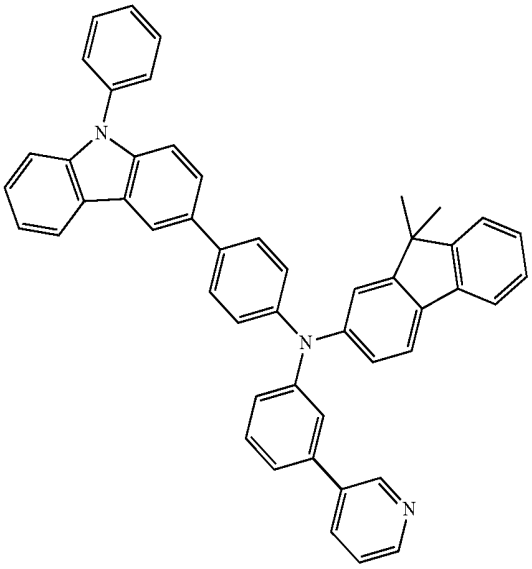
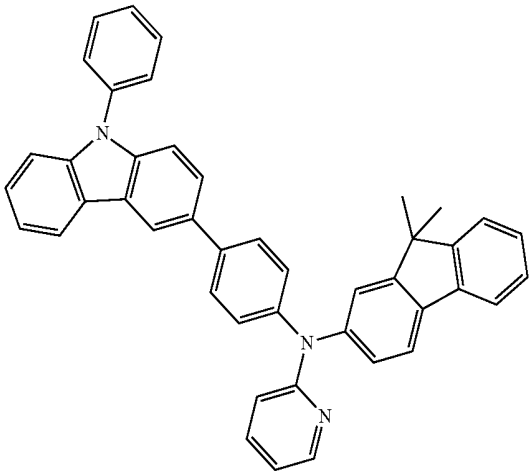
HT13



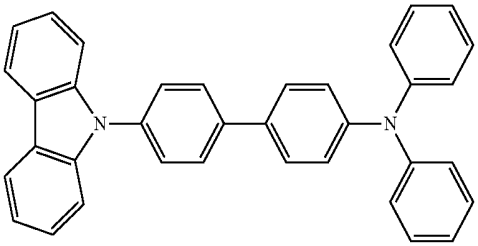
HT14



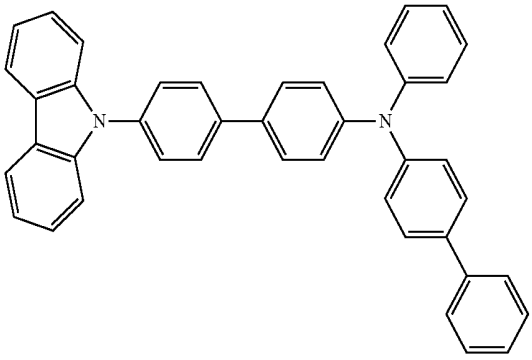
HT15



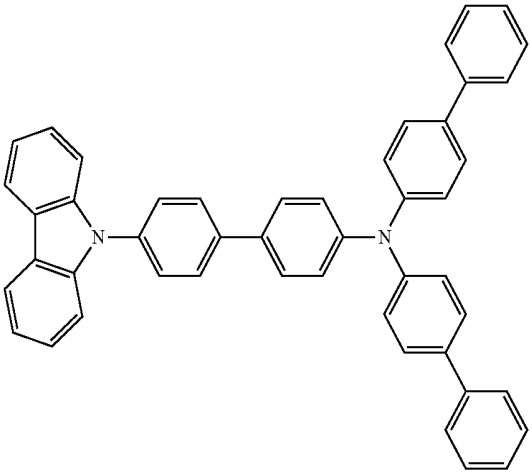
HT16



HT17



HT18



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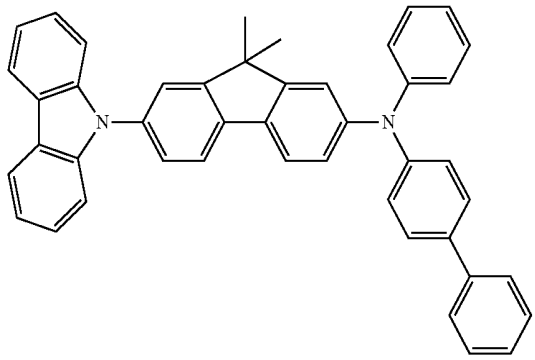
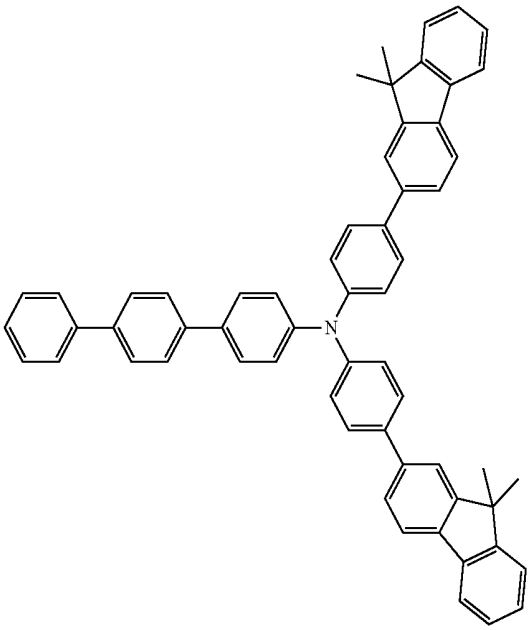
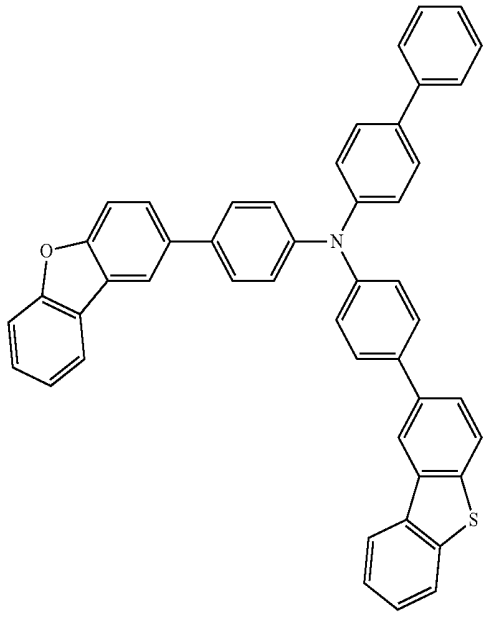
HT19



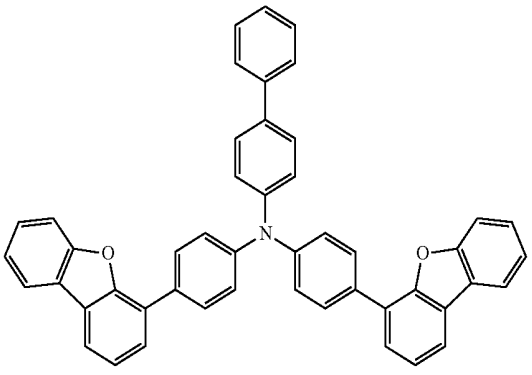
HT20



HT21



HT22



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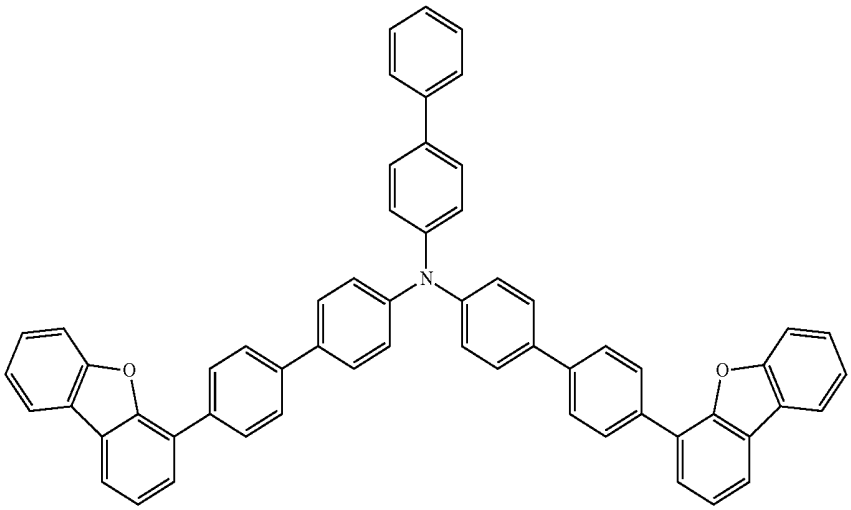
HT23



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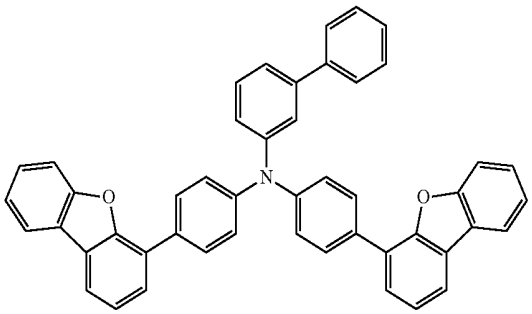

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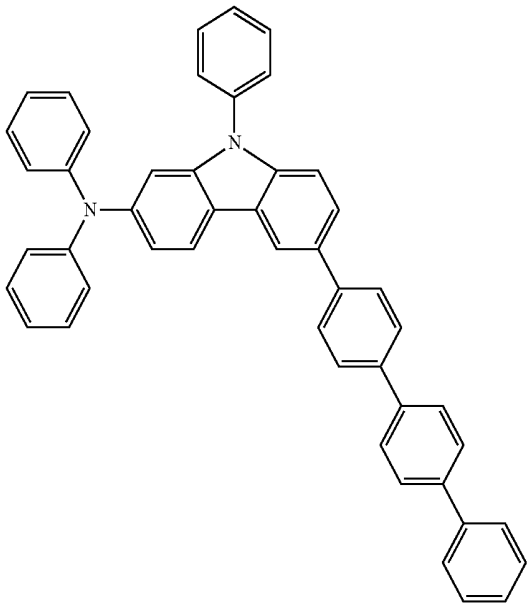

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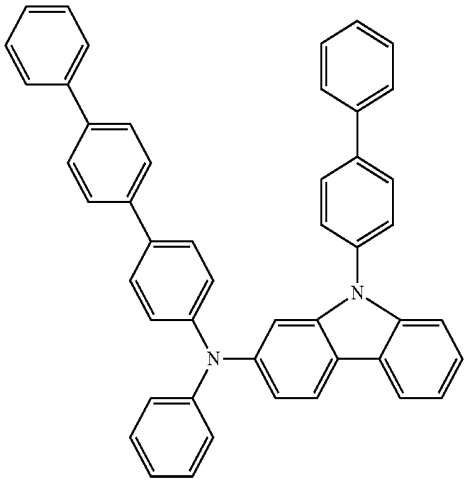
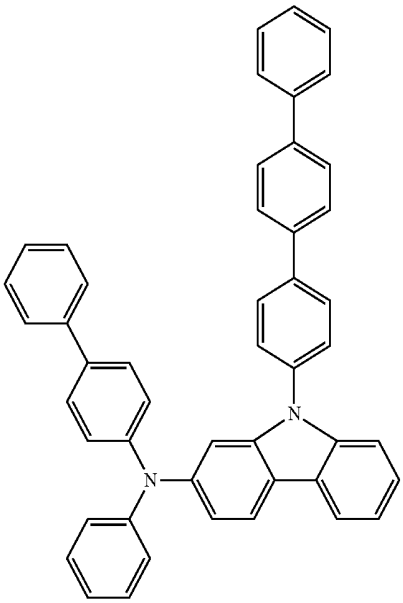
HT26



HT27



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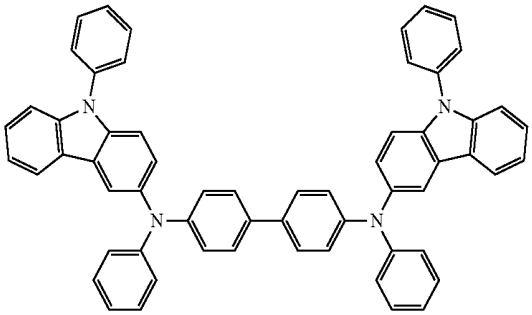
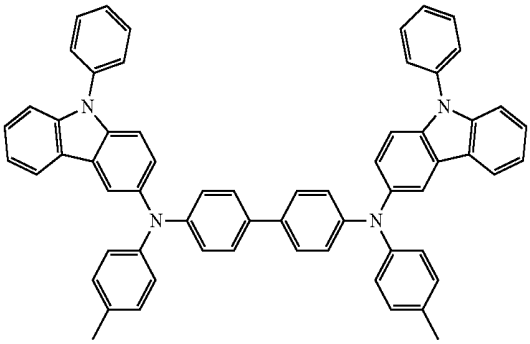


HT29



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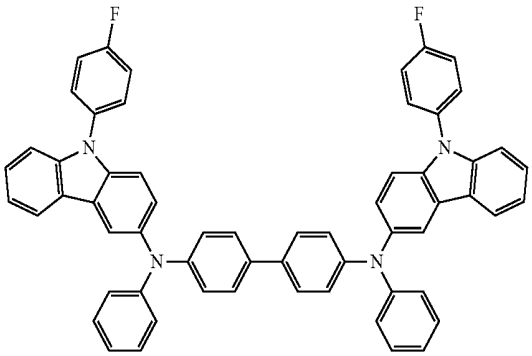
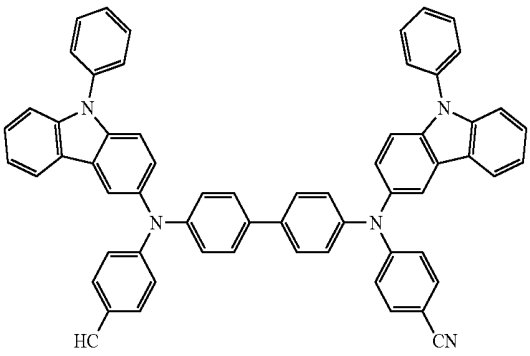


HT31



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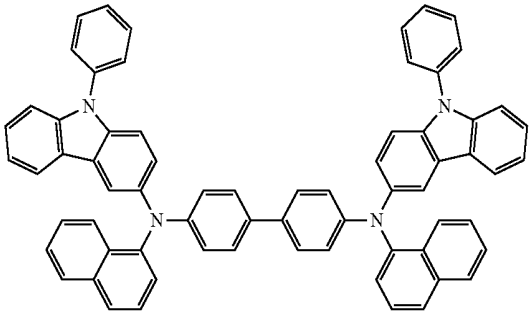
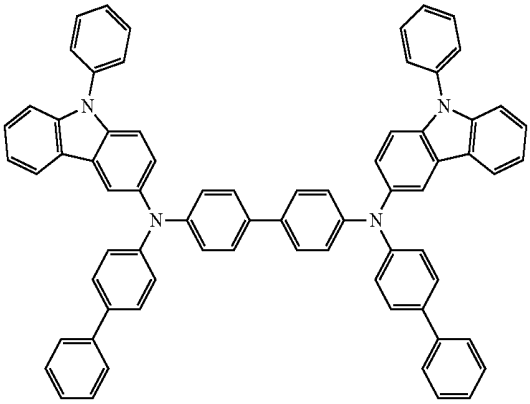
HT32



HT33



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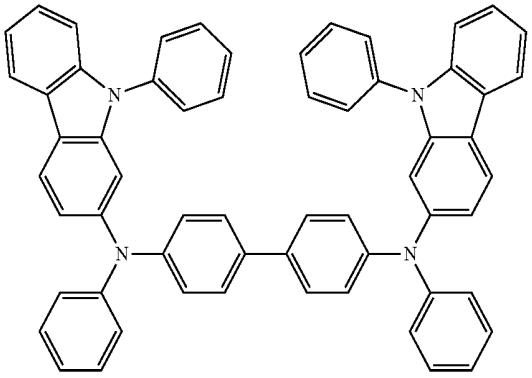
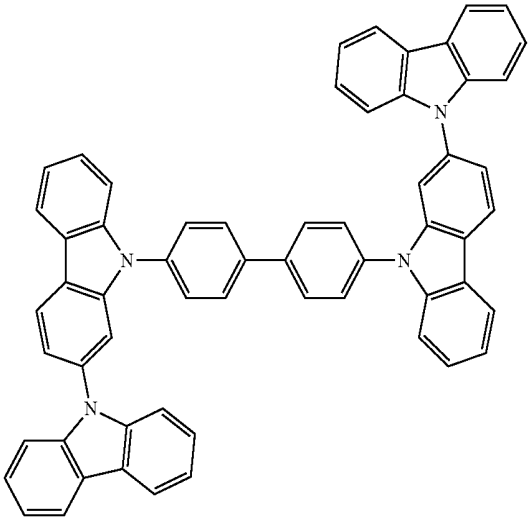
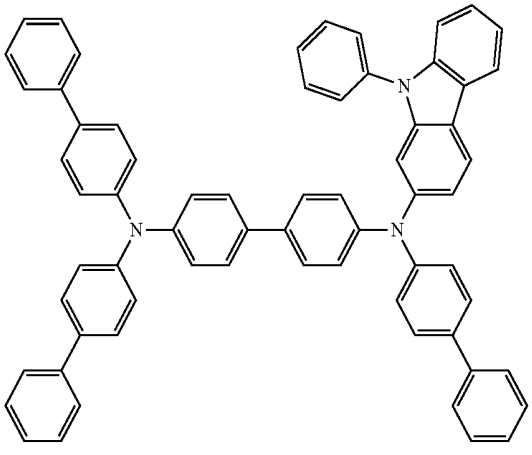


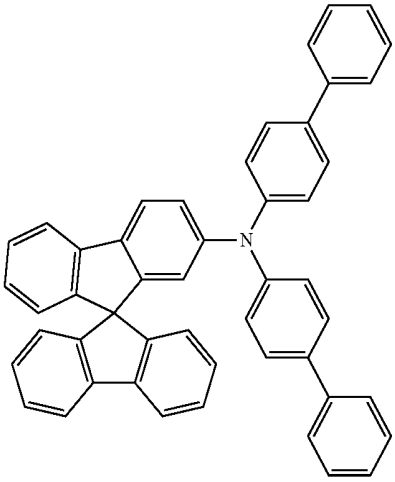
HT35



HT36



HT37



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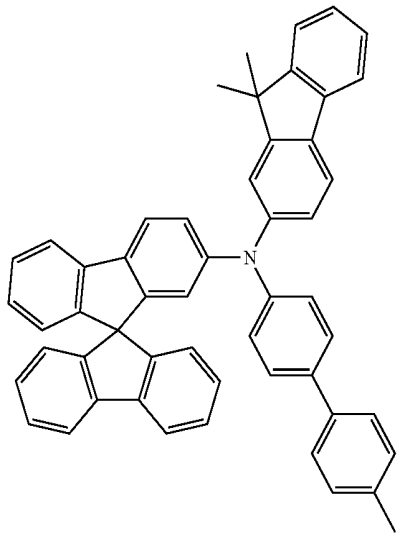
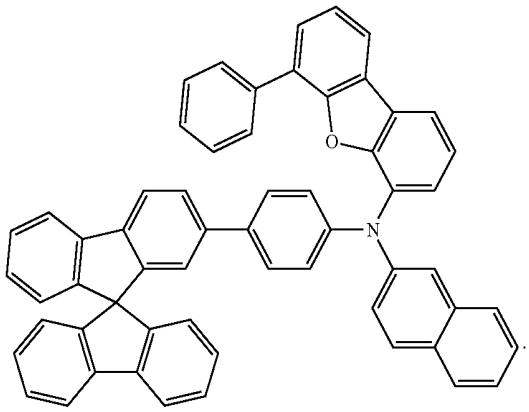
HT38



HT39



[0143] A thickness of the hole transport region **150***a* may be in a range of about 100 Å to about 10,000 Å, for example, about 100 Å to about 1,000 Å. When the hole transport region **150***a* includes at least one selected from a hole injection layer and a hole transport layer, the thickness of the hole injection layer may be in a range of about 100 Å to about 9,000 Å, and for example, about 100 Å to about 1,000 Å, and the thickness of the hole transport layer may be in a range of about 50 Å to about 2,000 Å, and for example, about 100 Å to about 1,500 Å. When the thicknesses of the hole transport region **150***a*, 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.

[0144] The emission auxiliary layer may increase light-emission efficiency by compensating for an optical resonance distance according to the wavelength of light emitted by an emission layer, and the electron blocking layer may block the flow of electrons from an electron transport region. The emission auxiliary layer and the electron blocking layer may include the materials as described above.

[0145] [p-Dopant]

[0146] The hole transport region **150***a* may further include, in addition to these materials, a charge-generation material for the improvement of conductive properties. The charge-generation material may be homogeneously or non-homogeneously dispersed in the hole transport region **150***a*.

[0147] The charge-generation material may be, for example, a p-dopant.

[0148] In one or more embodiments, a lowest unoccupied molecular orbital (LUMO) energy level of the p-dopant may be −3.5 eV or less.

[0149] In an implementation, the p-dopant may include at least one selected from a quinone derivative, a metal oxide, and a cyano group-containing compound.

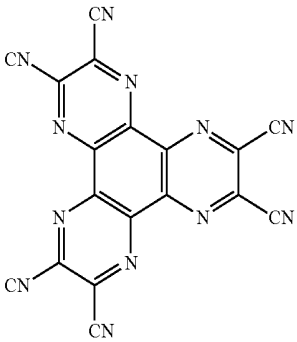
[0150] For example, the p-dopant may include at least one selected from:

[0151] a quinone derivative, such as tetracyanoquinodimethane (TCNQ) and 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F4-TCNQ);

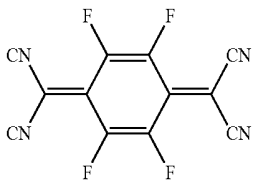
[0152] a metal oxide, such as tungsten oxide or molybdenum oxide;

[0153] 1,4,5,8,9,11-hexaazatriphenylene-hexacarbonitrile (HAT-CN); and

[0154] a compound represented by Formula 221 below:

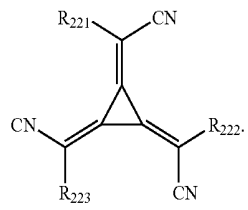


<HAT-CN>



<F4-TCNQ>

<Formula 221>



[0155] In Formula 221,

[0156] 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, and a C_1-C_{20} alkyl group substituted with —I.

[0157] [Emission Layer **150***b* in Organic Layer **150**]

[0158] When the organic light-emitting device **10** is a full-color organic light-emitting device, the emission layer **150***b* may be patterned into a red emission layer, a green emission layer, or a blue emission layer, according to a sub-pixel. In one or more embodiments, the emission layer **150***b* may have a stacked structure of two or more layers selected from a red emission layer, a green emission layer, and a blue emission layer, in which the two or more layers contact each other or are separated from each other. In an implementation, the emission layer may include two or more materials selected from a red light-emitting material, a green light-emitting material, and a blue light-emitting material, in which the two or more materials are mixed with each other in a single layer to emit white light.

[0159] The emission layer **150***b* may include a host and a dopant. The dopant may include at least one selected from a phosphorescent dopant and a fluorescent dopant.

[0160] An amount of the dopant in the emission layer **150***b* may be, in general, in a range of about 0.01 parts by weight to about 15 parts by weight based on 100 parts by weight of the host.

[0161] A thickness of the emission layer **150***b* may be in a range of about 100 Å to about 1,000 Å, for example, about 200 Å to about 600 Å. When the thickness of the emission layer **150***b* is within this range, excellent light-emission characteristics may be obtained without a substantial increase in driving voltage.

[0162] [Host in Emission Layer **150***b*]

[0163] In an implementation, the host may further include a compound represented by Formula 301:

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

[0164] In Formula 301,

[0165] Ar_{301} may be a substituted or unsubstituted C_5-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group,

[0166] xb11 may be 1, 2, or 3,

[0167] L_{301} is selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3-C_{10} cycloalkenylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6-C_{60} arylene group, a substituted or unsubstituted C_1-C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group;

[0168] xb1 may be an integer from 0 to 5,

[0169] R_{301} may be selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_2-C_{60} alkynyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, $—Si(Q_{301})(Q_{302})(Q_{303})$, $—N(Q_{301})(Q_{302})$, $—B(Q_{301})(Q_{302})$, $—C(=O)(Q_{301})$, $—S(=O)_2(Q_{301})$, and $—P(=O)(Q_{301})(Q_{302})$,

[0170] xb21 may be an integer from 1 to 5, and

[0171] 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, and a naphthyl group.

[0172] In one or more embodiments, Ar_{301} in Formula 301 may be selected from:

[0173] a naphthalene group, a fluorene group, a spirobifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, and a dibenzothiophene group;

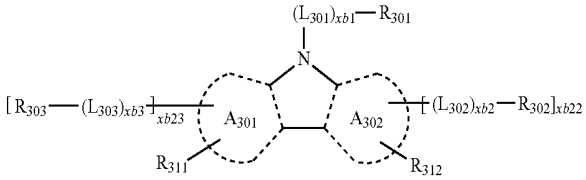
[0174] a naphthalene group, a fluorene group, a spirobifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, and a dibenzothiophene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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, $—Si(Q_{31})(Q_{32})(Q_{33})$, $—N(Q_{31})(Q_{32})$, $—B(Q_{31})(Q_{32})$, $—C(=O)(Q_{31})$, $—S(=O)_2(Q_{31})$, and $—P(=O)(Q_{31})(Q_{32})$; and

[0175] Q_{31} to Q_{33} may each independently be selected from a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

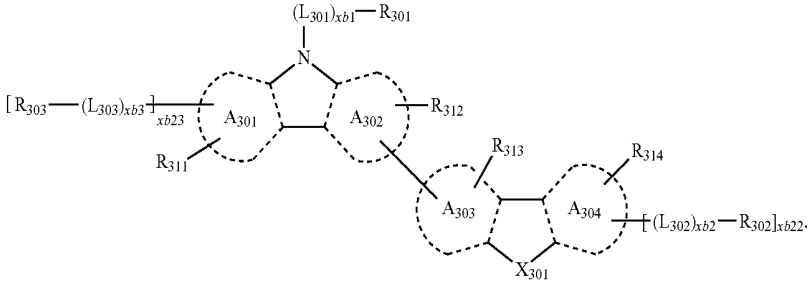
[0176] When xb11 in Formula 301 is two or more, two or more of Ar_{301}(s) may be linked via a single bond.

[0177] In an implementation, the compound represented by Formula 301 may be represented by Formula 301-1 or 301-2:

<Formula 301-1>



<Formula 301-2>



[0178] In Formulae 301-1 and 301-2,

[0179] A_{301} to A_{304} may each independently be selected from a benzene group, a naphthalene group, a phenanthrene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a pyridine group, a pyrimidine group, an indene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, an indole group, a carbazole group, a benzocarbazole group, a dibenzocarbazole group, a furan group, a benzofuran group, a dibenzofuran group, a naphthofuran group, a benzonaphthofuran group, a dinaphthofuran group, a thiophene group, a benzothiophene group, a dibenzothiophene group, a naphthothiophene group, a benzonaphthothiophene group, and a dinaphthothiophene group,

[0180] X_{301} may be O, S, or N-[$(L_{304})_{xb4}$-R_{304}],

[0181] 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 —$Si(Q_{31})(Q_{32})(Q_{33})$, —$N(Q_{31})(Q_{32})$, —$B(Q_{31})(Q_{32})$, —$C(=O)(Q_{31})$, —$S(=O)_2(Q_{31})$, and —$P(=O)(Q_{31})(Q_{32})$,

[0182] xb22 and xb23 may each independently be 0, 1, or 2,

[0183] L_{301}, xb1, R_{301}, and Q_{31} to Q_{33} may be the same as described above,

[0184] L_{302} to L_{304} may each independently be the same as described in connection with L_{301},

[0185] xb2 to xb4 may each independently be the same as described in connection with xb1,

[0186] R_{302} to R_{304} may each independently be the same as described in connection with R_{301}.

[0187] For example, L_{301} to L_{304} in Formulae 301, 301-1, and 301-2 may each independently be selected from:

[0188] 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;

[0189] 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, $—Si(Q_{31})(Q_{32})(Q_{33})$, $—N(Q_{31})(Q_{32})$, $—B(Q_{31})(Q_{32})$, $—C(=O)(Q_{31})$, $—S(=O)_2(Q_{31})$, and $—P(=O)(Q_{31})(Q_{32})$; and

[0190] Q_{31} and Q_{33} may be the same as described above.

[0191] In an implementation, R_{301} to R_{304} in Formulae 301, 301-1, and 301-2 may each independently be selected from:

[0192] 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; and

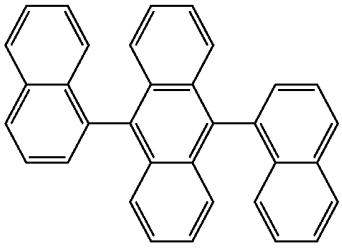
[0193] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, 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, 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, $—Si(Q_{31})(Q_{32})(Q_{33})$, $—N(Q_{31})(Q_{32})$, $—B(Q_{31})(Q_{32})$, $—C(=O)(Q_{31})$, $—S(=O)_2(Q_{31})$, and $—P(=O)(Q_{31})(Q_{32})$; and

[0194] Q_{31} and Q_{33} may be the same as described above.

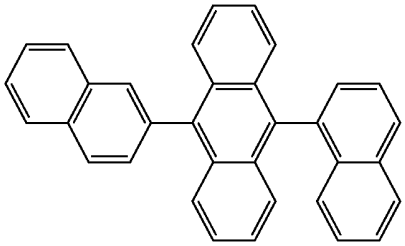
[0195] In an implementation, the host may include an alkaline earth metal complex. For example, the host may be selected from a Be complex (for example, Compound H55), a Mg complex, and a Zn complex.

[0196] In an implementation, the host may include at least one selected from 9,10-di(2-naphthyl)anthracene (ADN), 2-methyl-9,10-bis(naphthalen-2-yl)anthracene (MADN), 9,10-di-(2-naphthyl)-2-t-butyl-anthracene (TBADN), 4,4'-bis(N-carbazolyl)-1,1'-biphenyl (CBP), 1,3-di-9-carbazolyl-benzene (mCP), 1,3,5-tri(carbazol-9-yl)benzene (TCP), and Compounds H1 to H55:

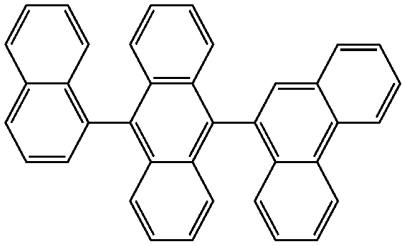
H1



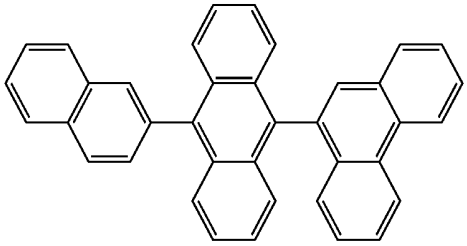
H2



H3



H4



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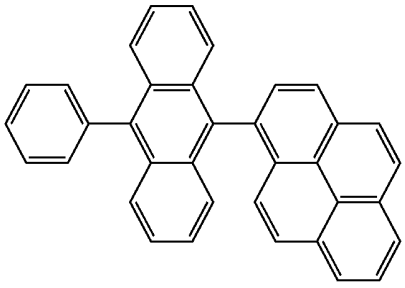

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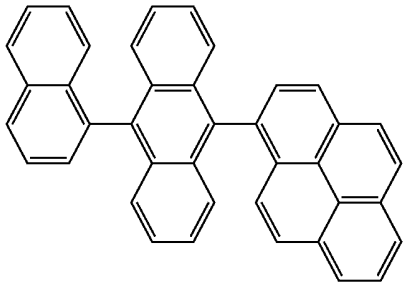
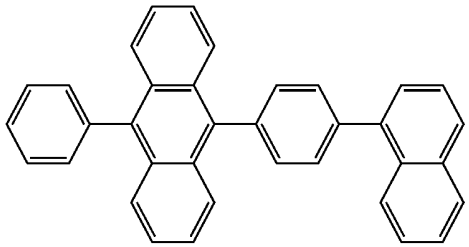
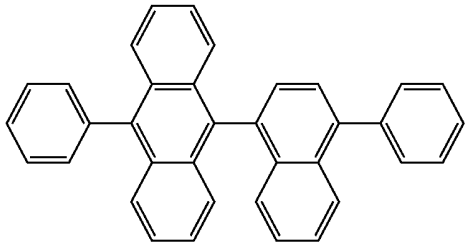
H6



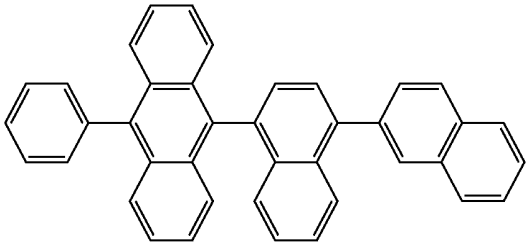
H7



H8



H9



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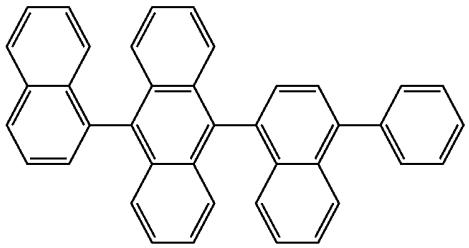

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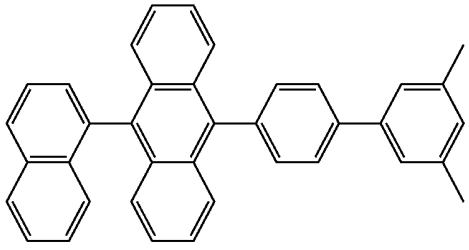

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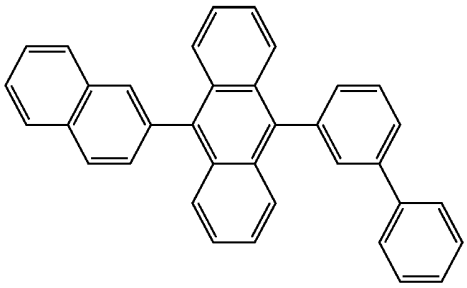
H12



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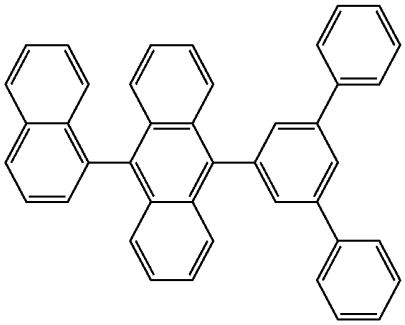

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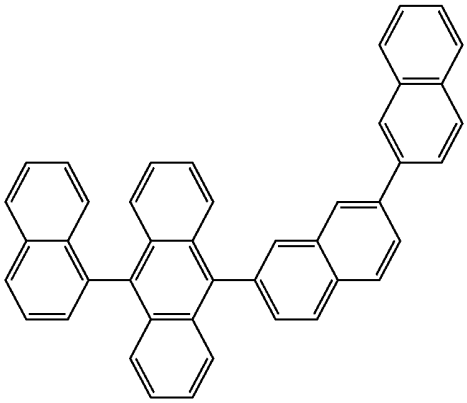

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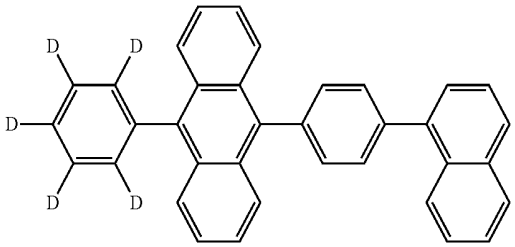

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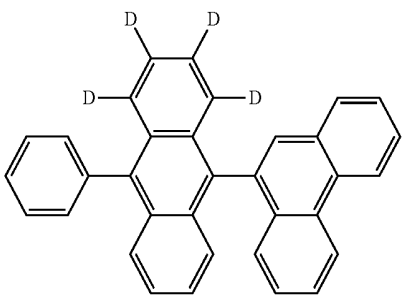

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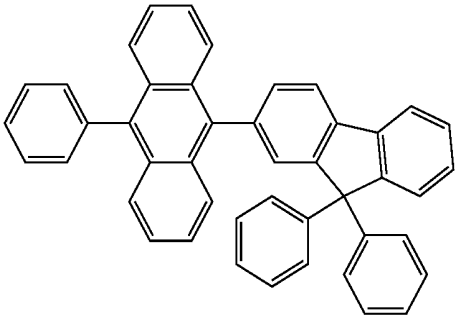

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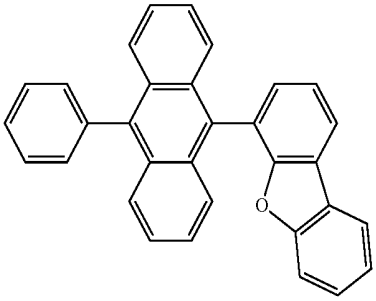

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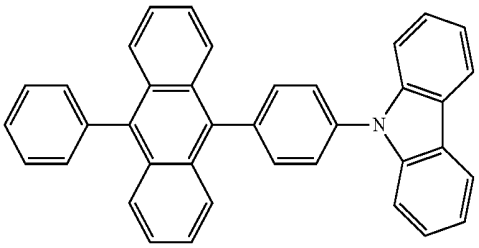

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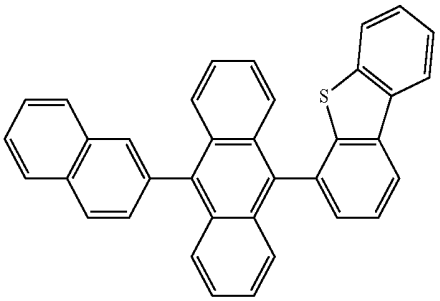

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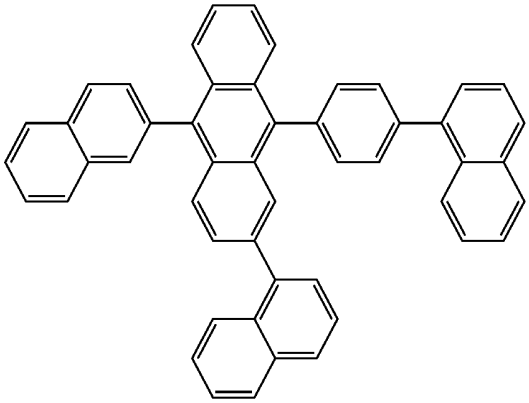

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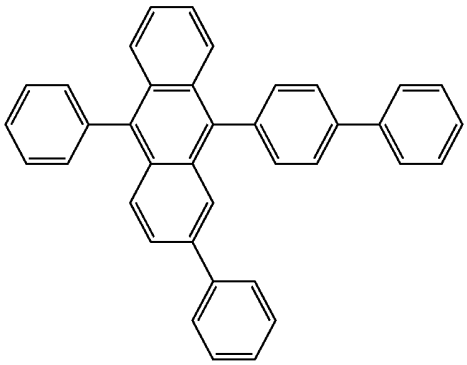

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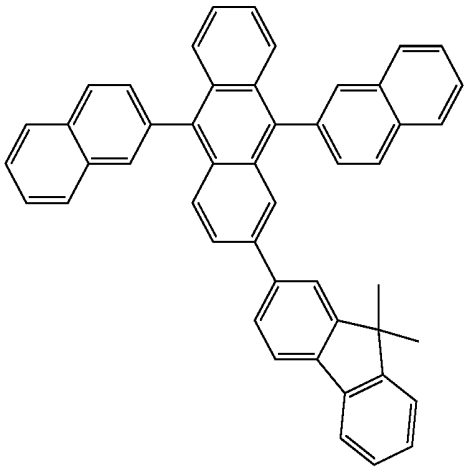

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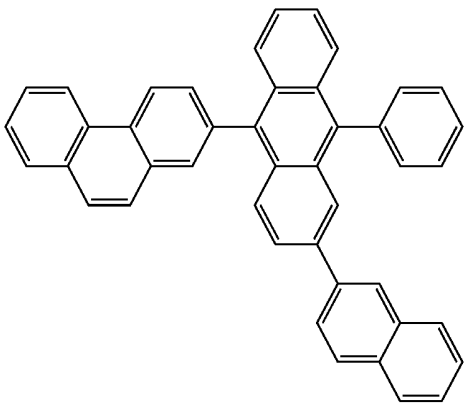

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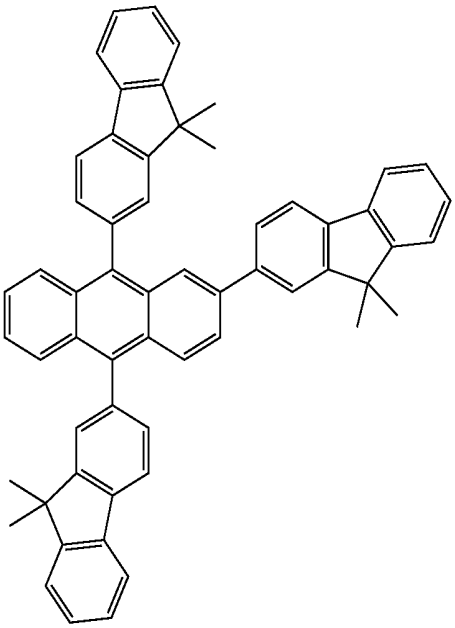

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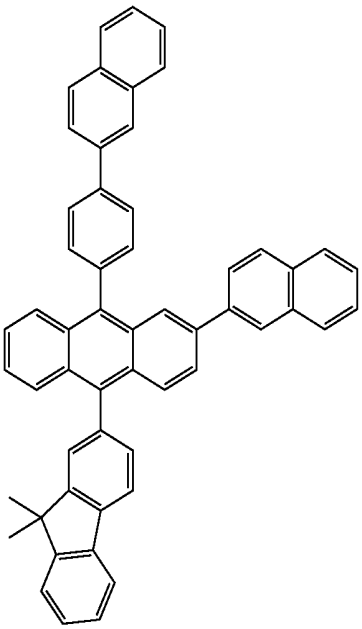

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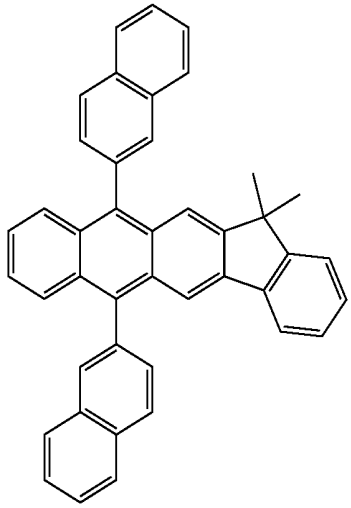

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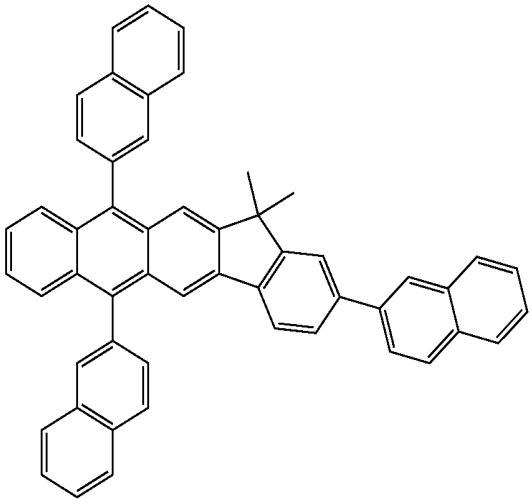

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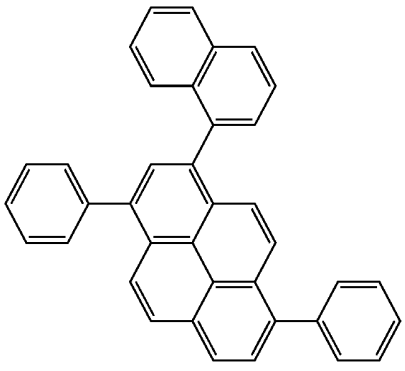

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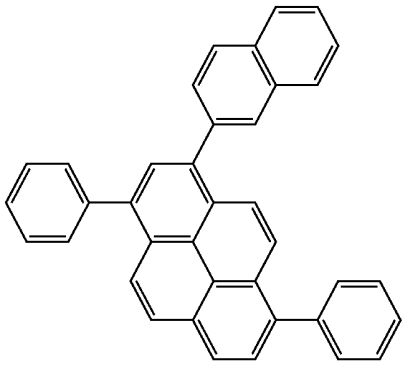

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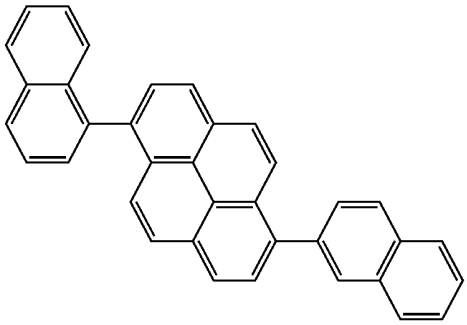
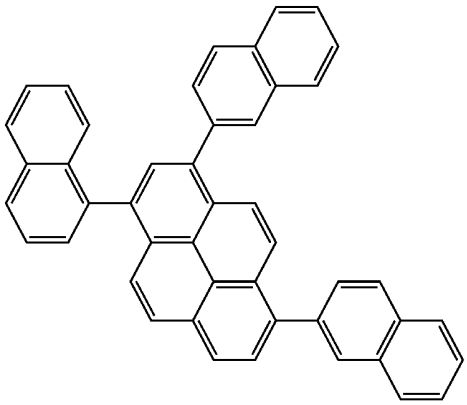


H32



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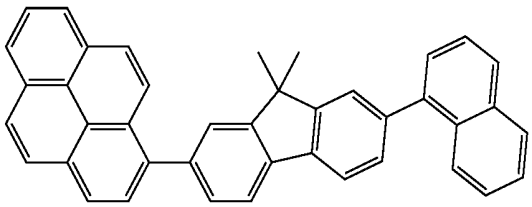

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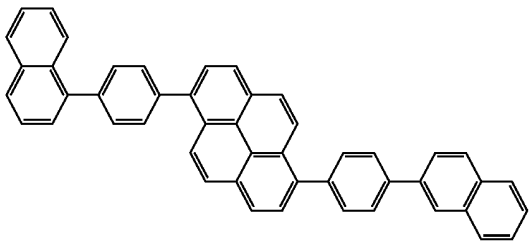

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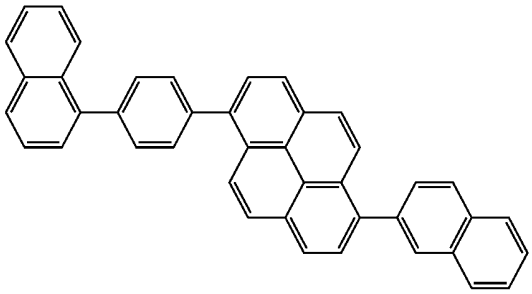

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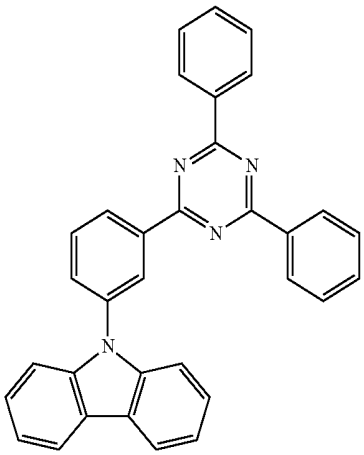

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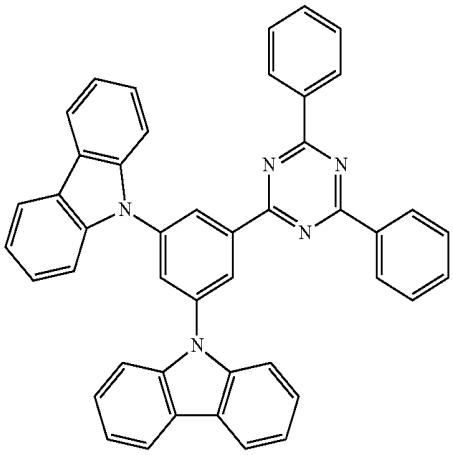

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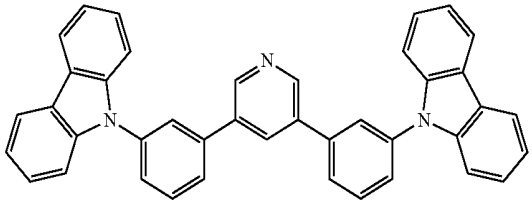

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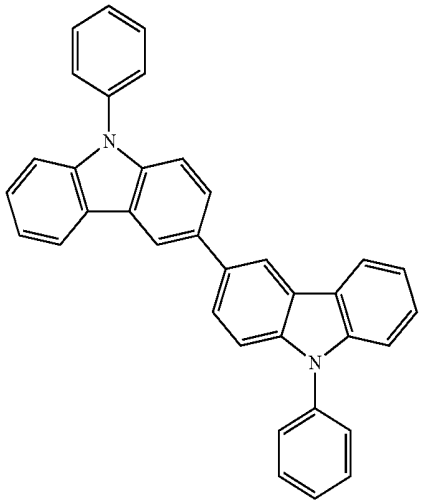

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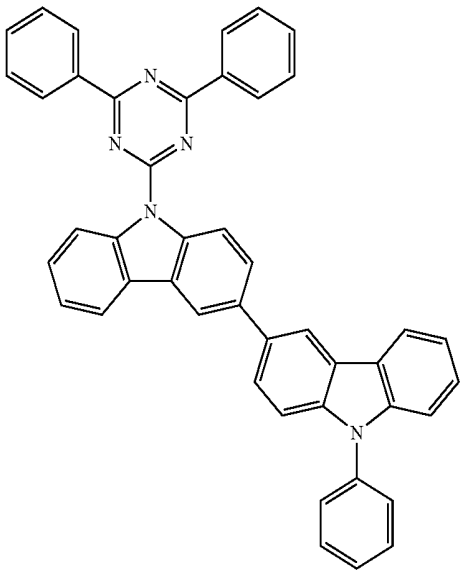
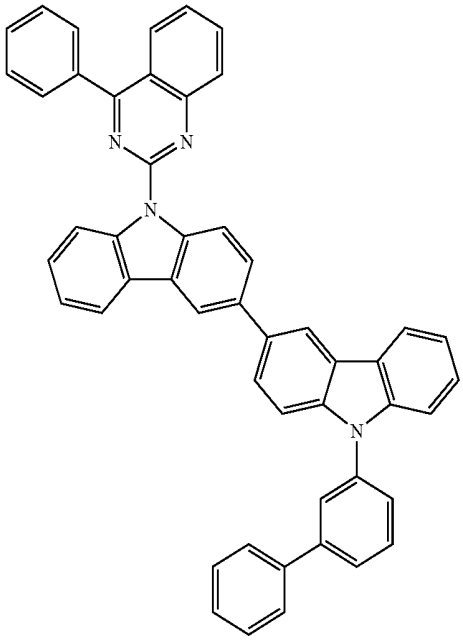


H41



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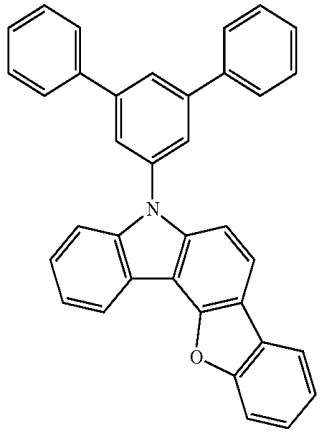
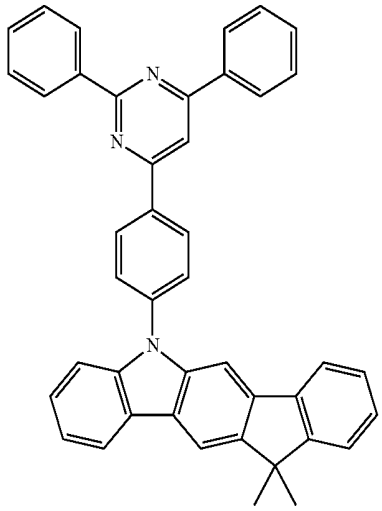
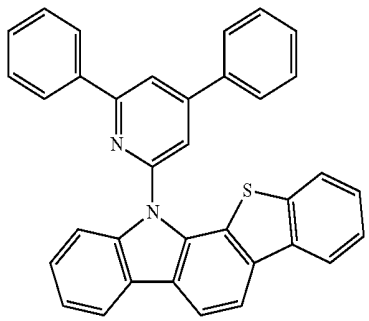
H42



H43



H44



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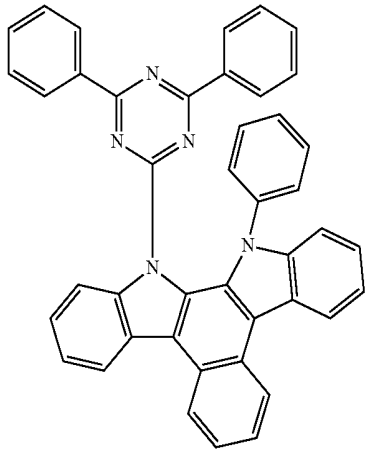
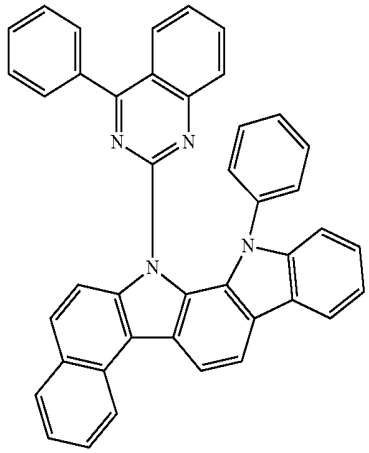
H45



H46



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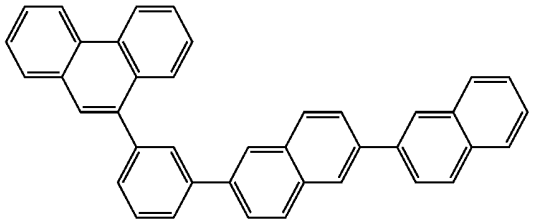

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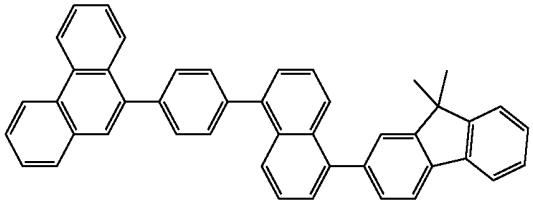

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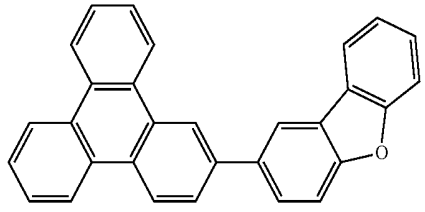

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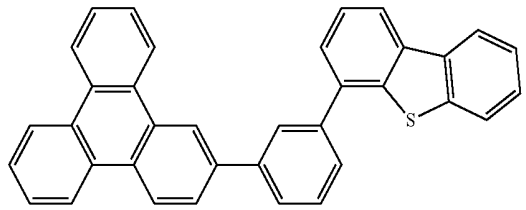

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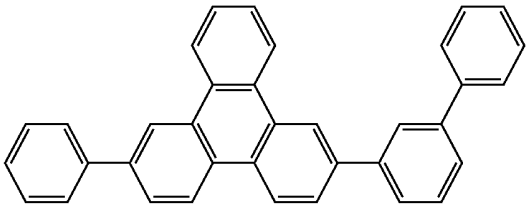

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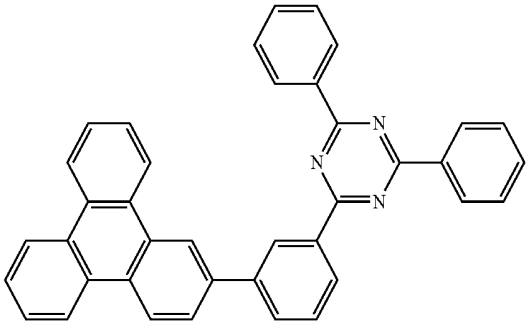

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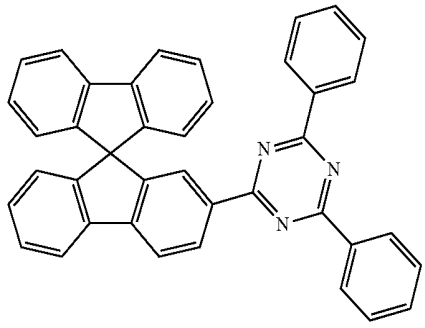

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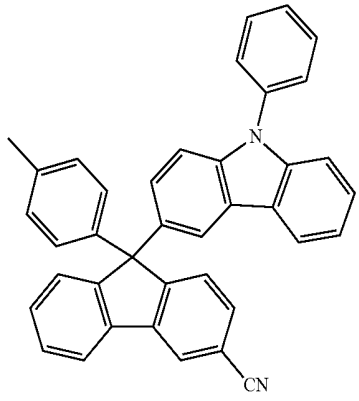

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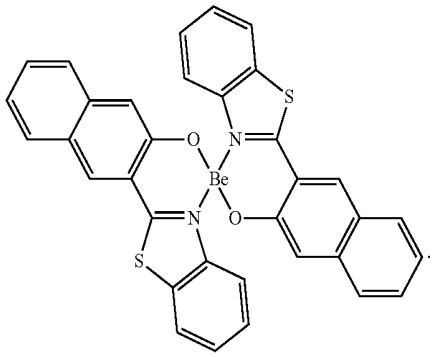
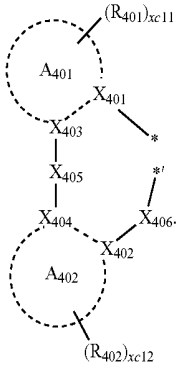


[0197] [Phosphorescent Dopant Included in Emission Layer **150***b* in Organic Layer **150**]

[0198] The phosphorescent dopant may include an organometallic complex represented by Formula 401:

<Formula 401>

<Formula 402>



[0199] In Formulae 401 and 402,

[0200] M may be selected from iridium (Ir), platinum (Pt), palladium (Pd), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), rhodium (Rh), and thulium (Tm),

[0201] L_{401} may be selected from ligands represented by Formula 402, and xc1 may be 1, 2, or 3, wherein, when xc1 is two or more, two or more L_{401}(s) may be identical to or different from each other,

[0202] L_{402} may be an organic ligand, and xc2 may be an integer from 0 to 4, wherein, when xc2 is two or more, two or more L_{402}(s) may be identical to or different from each other,

[0203] X_{401} to X_{404} may each independently be nitrogen or carbon,

[0204] X_{401} and X_{403} may be linked via a single bond or a double bond, and X_{402} and X_{404} may be linked via a single bond or a double bond,

[0205] 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,

[0206] X_{405} may be 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} and Q_{412} may be 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,

[0207] X_{406} may be a single bond, O, or S,

[0208] 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)(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}), and 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, and a C_1-C_{20} heteroaryl group,

[0209] xc11 and xc12 may each independently be an integer from 0 to 10, and

[0210] * and *' in Formula 402 each indicate a binding site to May be in Formula 401.

[0211] In one or more embodiments, 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, and a dibenzothiophene group.

[0212] In one or more embodiments, in Formula 402, i) X_{401} may be nitrogen, and X_{402} may be carbon, or ii) X_{401} and X_{402} may each be nitrogen at the same time.

[0213] In one or more embodiments, R_{402} and R_{402} in Formula 401 may each independently be selected from:

[0214] 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;

[0215] 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, and a norbornenyl group;

[0216] 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;

[0217] 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, and a dibenzothiophenyl group;

[0218] —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}); and

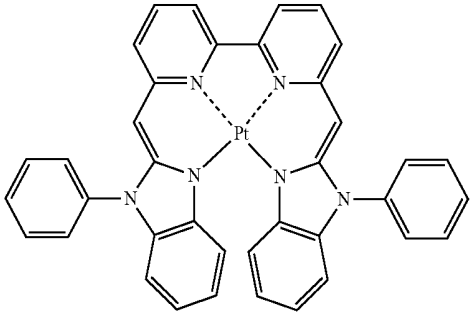
[0219] Q_{401} to Q_{403} may each independently be selected from a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, and a naphthyl group.

[0220] In one or more embodiments, when xc1 in Formula 401 is two or more, two A_{401}(s) in two or more L_{401}(s) may optionally be linked via X_{407}, which is a linking group, or two A_{402}(s) in two or more L_{401}(s) may optionally be linked via X_{408}, which is a linking group (see Compounds PD1 to PD4 and PD7). X_{407} and X_{408} may each independently be a single bond, *—O—*', *—S—*', *—C(═O)—*', *—N(Q_{413})-*, *—C(Q_{413})(Q_{414})-*', or *—C(Q_{413})=C(Q_{414})-*' (wherein Q_{413} and Q_{414} may each independently be 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).

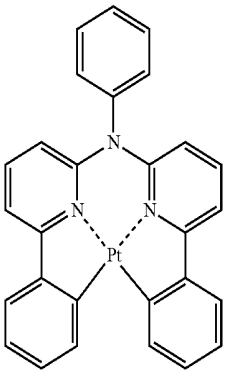
[0221] L_{402} in Formula 401 may be a monovalent, divalent, or trivalent organic ligand. For example, L_{402} may be selected from halogen, diketone (for example, acetylacetonate), carboxylic acid (for example, picolinate), —C(═O), isonitrile, —CN, and phosphorus containing material (for example, phosphine, or phosphite).

[0222] In an implementation, the phosphorescent dopant may be selected from, for example, Compounds PD1 to PD25:

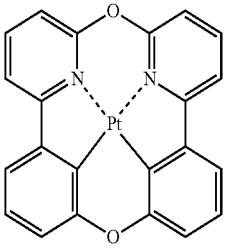
PD1



PD2



PD3



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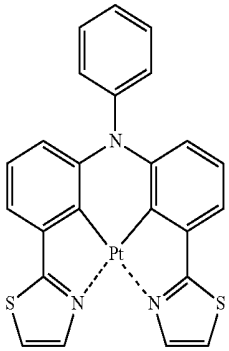
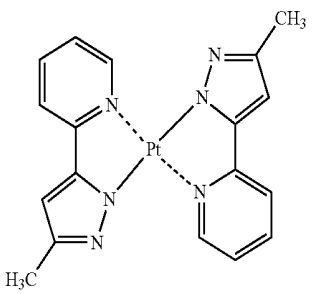


PD5



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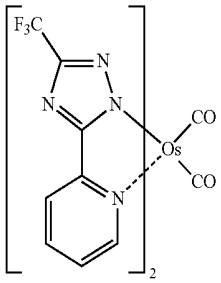
PD6



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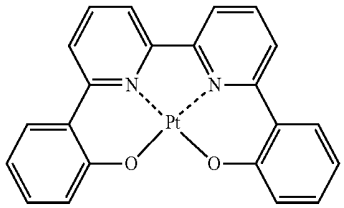

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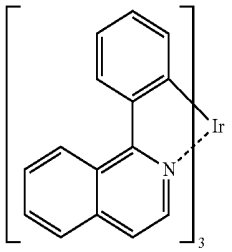

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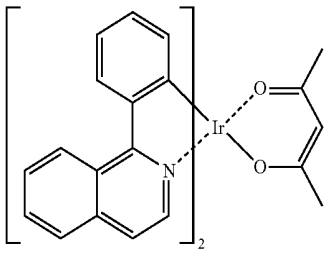

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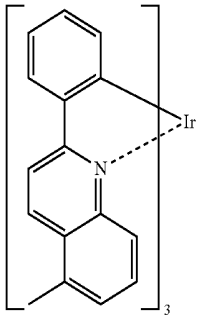

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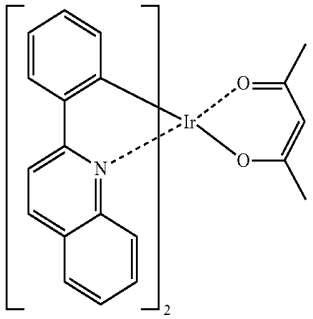

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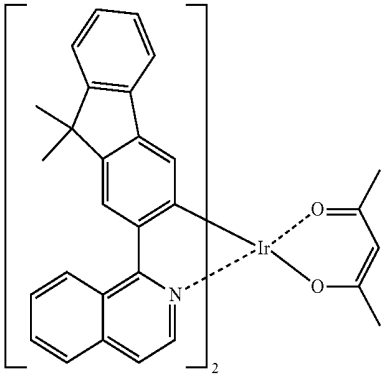

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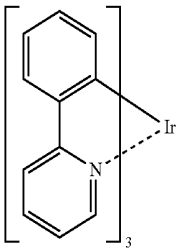

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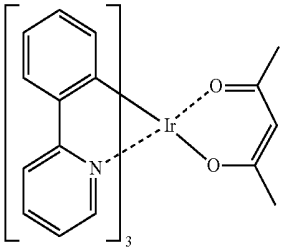

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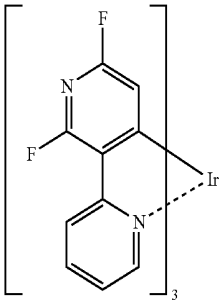

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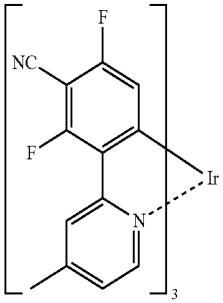

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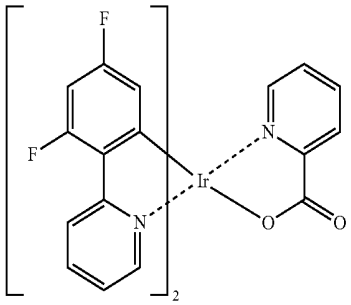

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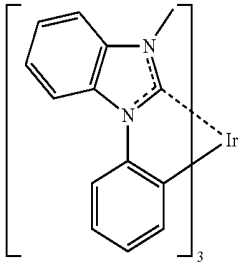

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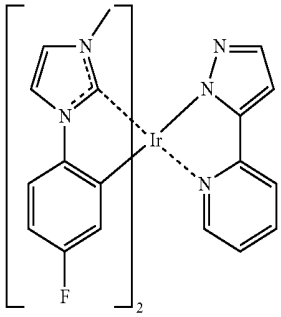

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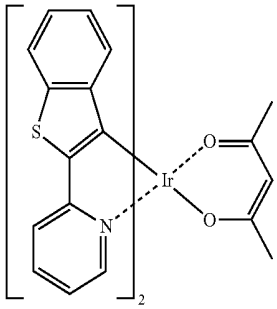

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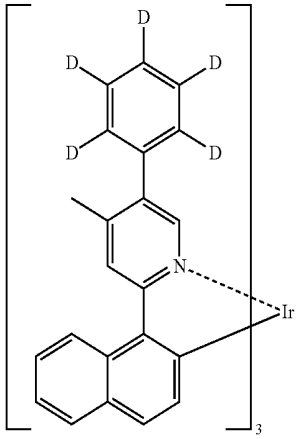

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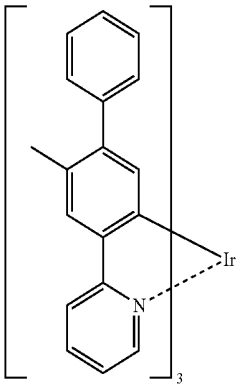
PD22



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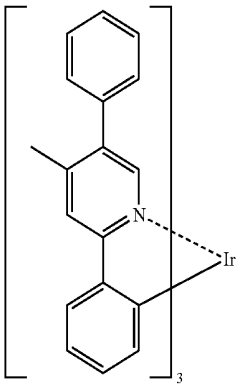
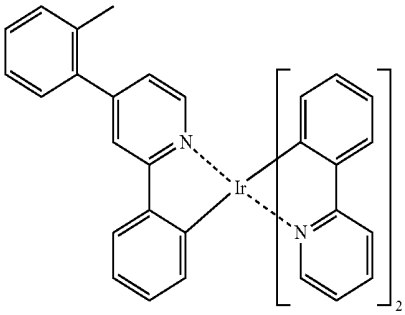
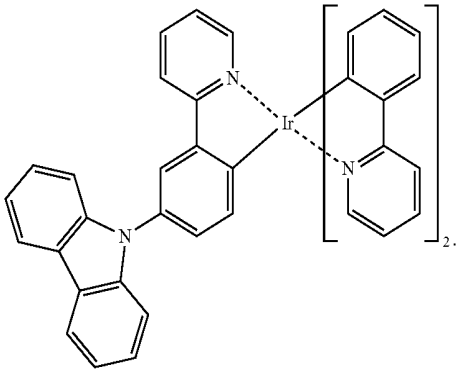


PD24



PD25

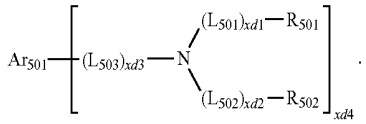


[0223] [Fluorescent Dopant in Emission Layer **150***b*]

[0224] The fluorescent dopant may include an arylamine compound or a styrylamine compound.

[0225] The fluorescent dopant may include a compound represented by Formula 501:

<Formula 501>



[0226] In Formula 501,

[0227] Ar_{501} may be a substituted or unsubstituted C_5-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group,

[0228] L_{501} to L_{503} may each independently be selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3-C_{10} cycloalkenylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6-C_{60} arylene group, a substituted or unsubstituted C_1-C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0229] xd1 to xd3 may each independently be an integer from 0 to 3;

[0230] 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, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, and

[0231] xd4 may be an integer from 1 to 6.

[0232] In one or more embodiments, Ar_{501} in Formula 501 may be selected from:

[0233] a naphthalene group, a heptalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, and an indenophenanthrene group; and

[0234] a naphthalene group, a heptalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, and an indenophenanthrene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0235] In one or more embodiments, L_{501} to L_{503} in Formula 501 may each independently be selected from:

[0236] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluore-

nylene 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; and

[0237] 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, and a pyridinyl group.

[0238] In one or more embodiments, R_{501} and R_{502} in Formula 501 may each independently be selected from:

[0239] 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;

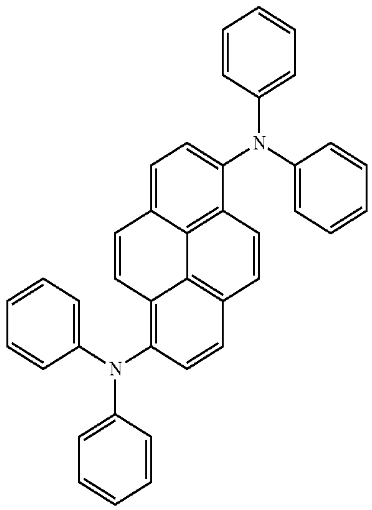
[0240] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, 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, and —Si(Q_{31})(Q_{32})(Q_{33}); and

[0241] Q_{31} to Q_{33} 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, and a naphthyl group.

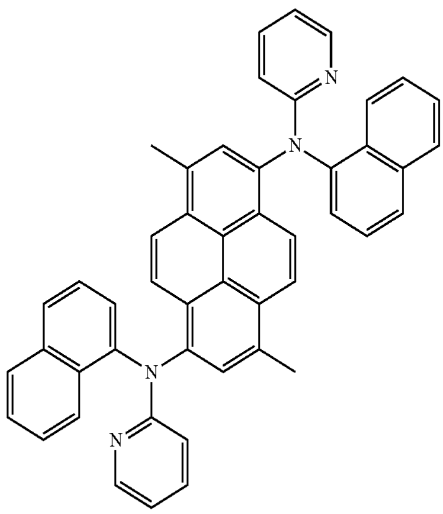
[0242] In an implementation, xd4 in Formula 501 may be 2.

[0243] In an implementation, the fluorescent dopant may be selected from Compounds FD1 to FD22:

FD1



FD2



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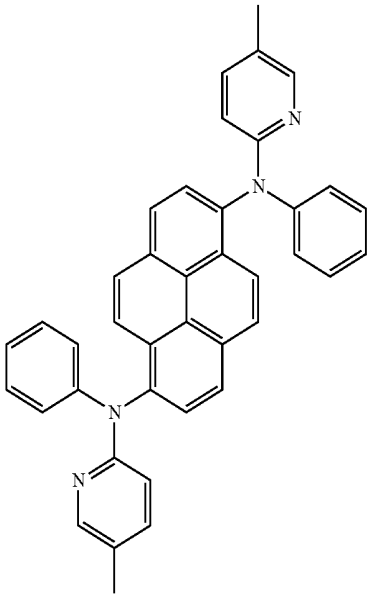
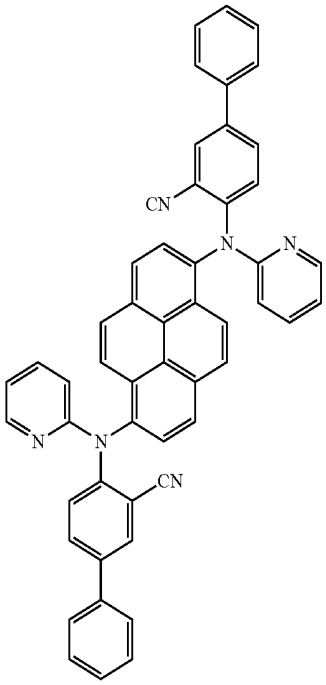
FD3



FD4



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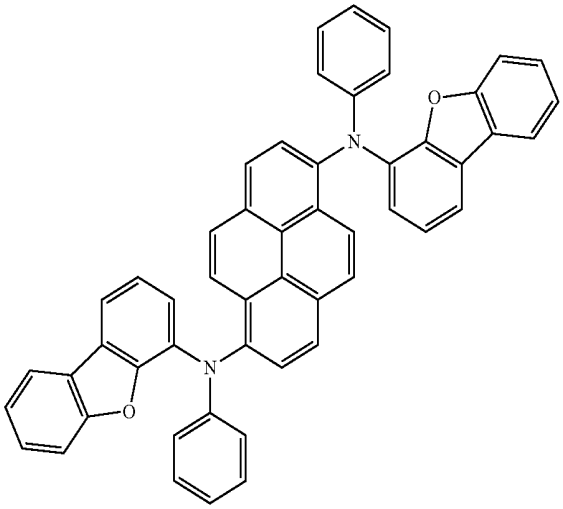
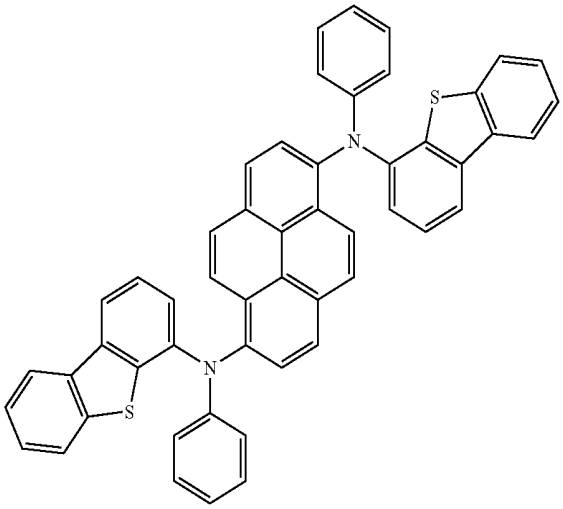
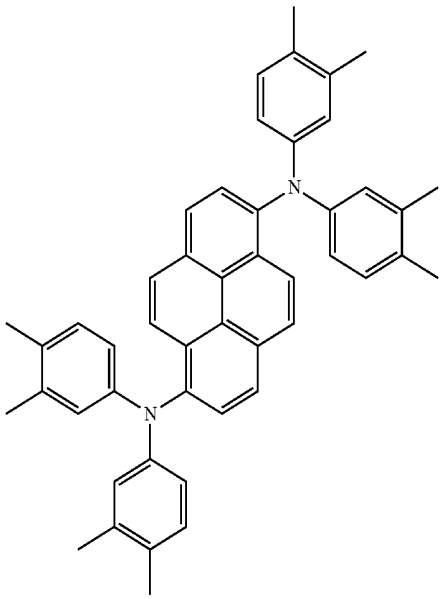
FD5



FD6



FD7



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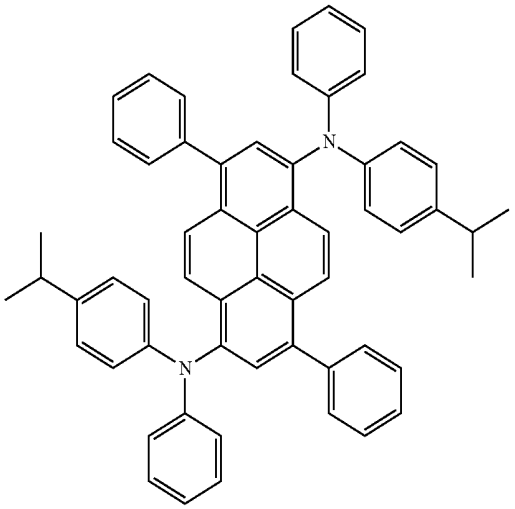
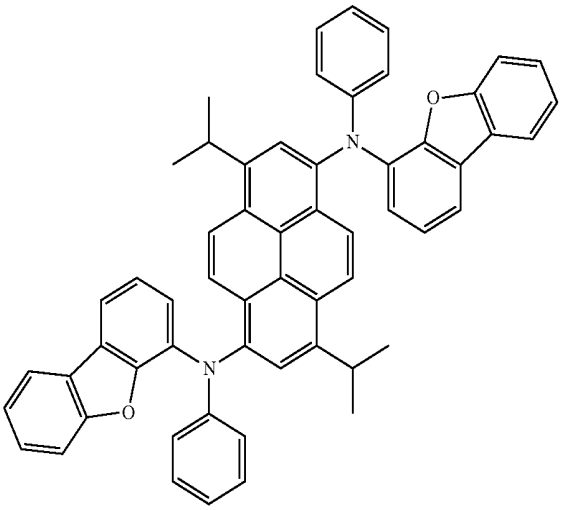
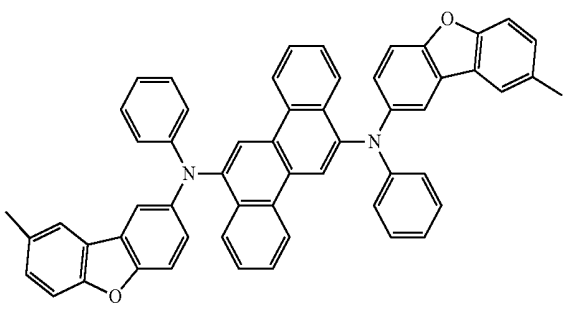
FD8



FD9



FD10



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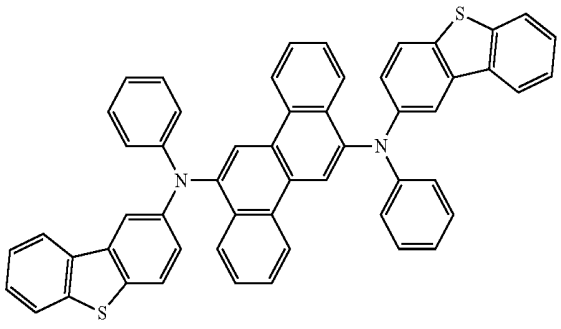
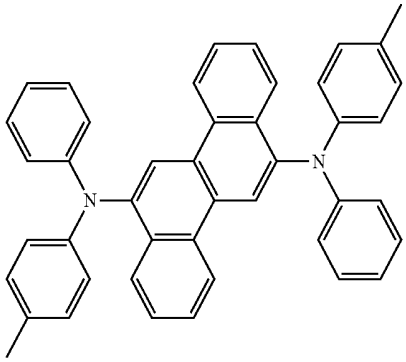
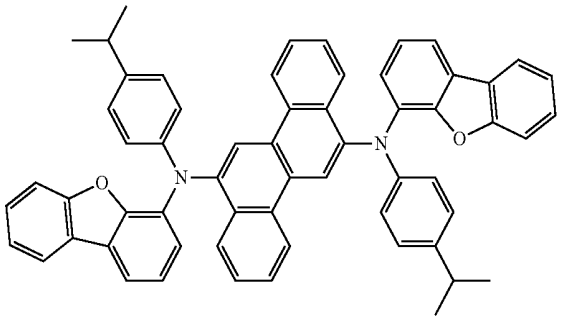
FD11



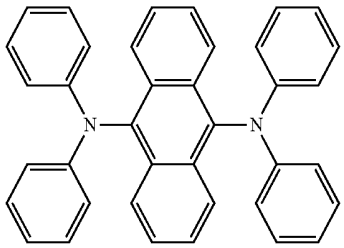
FD12



FD13



FD14



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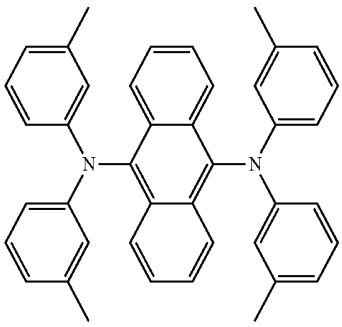
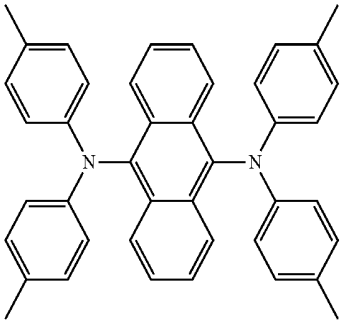
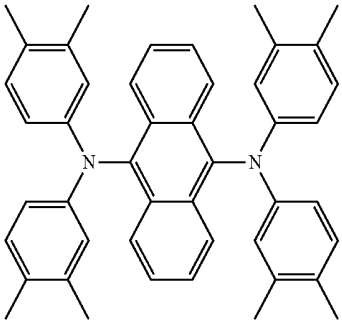
FD15



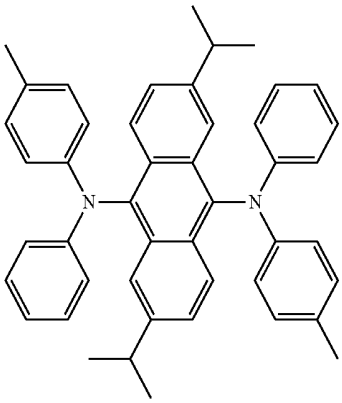
FD16



FD17



FD18



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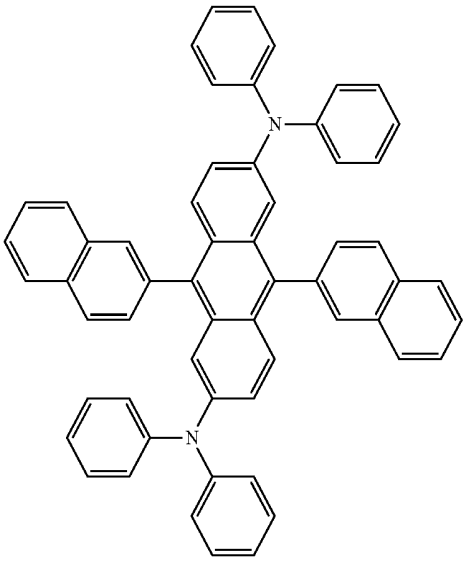
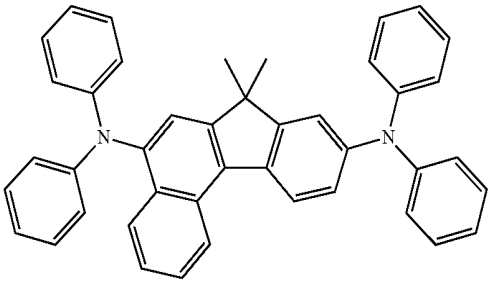
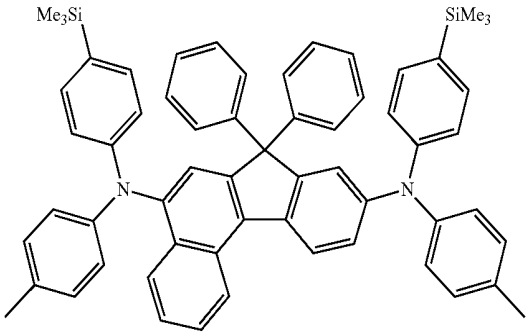
FD19



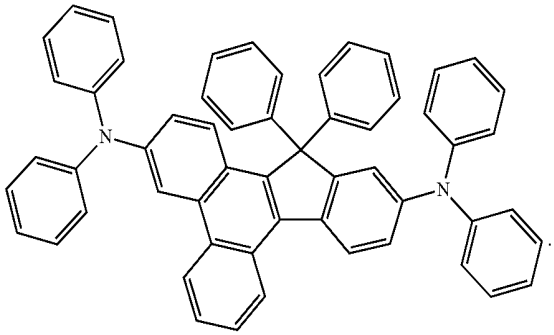
FD20



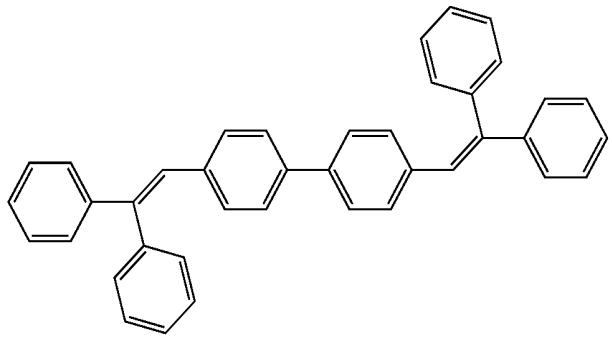
FD21



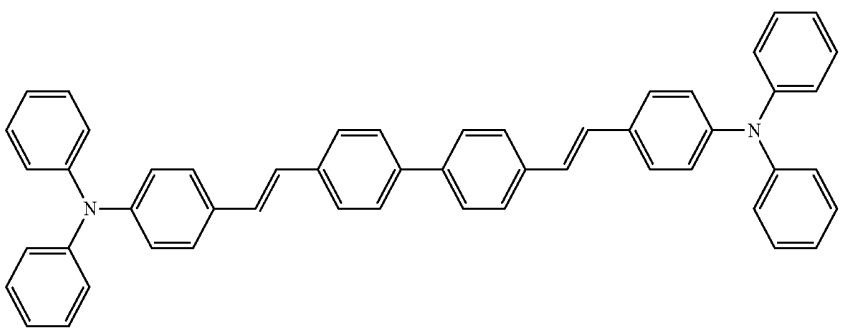
FD22



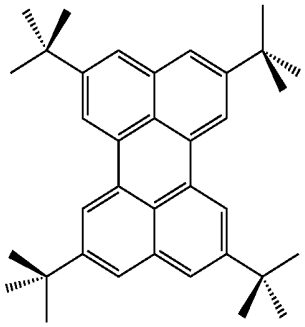
[0244] In an implementation, the fluorescent dopant may be selected from the following compounds.



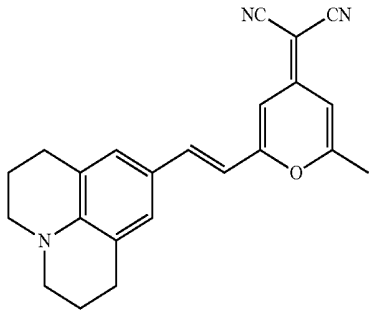
DPVBi



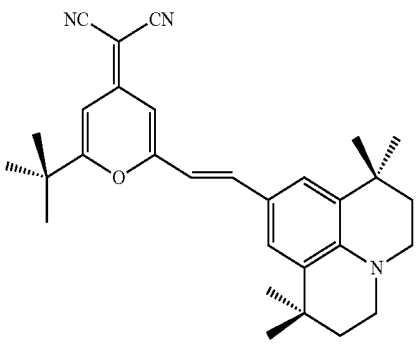
DPAVBi



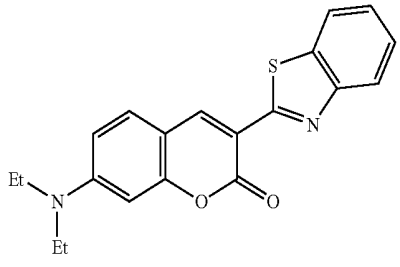
TBPe



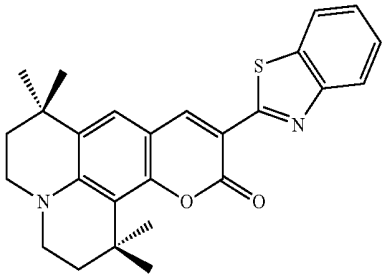
DCM



DCJTB



Coumarin 6



C545T

[0245] [Electron Transport Region **150***c* in Organic Layer **150**]

[0246] The electron transport region **150***c* may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

[0247] The electron transport region **150***c* may include at least one selected from a buffer layer, a hole blocking layer, an electron control layer, an electron transport layer, and an electron injection layer.

[0248] In an implementation, the electron transport region **150***c* 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 struc-

ture, or a buffer layer/electron transport layer/electron injection layer structure, wherein for each structure, constituting layers are sequentially stacked from the emission layer **150***b*.

[0249] In an implementation, the electron transport region **150***c* may include the condensed cyclic compound represented by Formula 1.

[0250] In an implementation, the electron transport region **150***c* (for example, a buffer layer, a hole blocking layer, an electron control layer, or an electron transport layer **150***c* in the electron transport region) may include a metal-free compound containing at least one π electron-depleted nitrogen-containing ring.

[0251] The "π electron-depleted nitrogen-containing ring" indicates a C_1-C_{60} heterocyclic group having at least one *—N=*' moiety as a ring-forming moiety.

[0252] For example, the "π electron-depleted nitrogen-containing ring" may be i) a 60-membered to 7-membered heteromonocyclic group having at least one *—N=*' moiety, ii) a heteropolycyclic group in which two or more 5-membered to 7-membered heteromonocyclic groups each having at least one *—N=*' moiety are condensed with each other, or iii) a heteropolycyclic group in which at least one of 5-membered to 7-membered heteromonocyclic groups, each having at least one *—N=*' moiety, is condensed with at least one C_5-C_{60} carbocyclic group.

[0253] Examples of the π electron-depleted nitrogen-containing ring 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, and an azacarbazole.

[0254] For example, the electron transport region **150***c* may include a compound represented by Formula 601:

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

[0255] In Formula 601,

[0256] Ar_{601} may be a substituted or unsubstituted C_5-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group,

[0257] xe11 may be 1, 2, or 3,

[0258] L_{601} is selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3-C_{10} cycloalkenylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6-C_{60} arylene group, a substituted or unsubstituted C_1-C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0259] xe1 may be an integer from 0 to 5,

[0260] R_{601} may be selected from a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —$Si(Q_{601})(Q_{602})(Q_{603})$, —$C(=O)(Q_{601})$, —$S(=O)_2(Q_{601})$, and —$P(=O)(Q_{601})(Q_{602})$,

[0261] Q_{601} to Q_{603} may each independently be a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group, and

[0262] xe21 may be an integer from 1 to 5.

[0263] In an implementation, at least one of Ar_{601}(s) in the number of xe11 and R_{601}(s) in the number of xe21 may include the n electron-depleted nitrogen-containing ring.

[0264] In an implementation, ring Ar_{601} in Formula 601 may be selected from:

[0265] a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, a dibenzothiophene group, a carbazole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, a naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, a phenanthroline group, a phenazine group, a benzimidazole group, an isobenzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, thiadiazol group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group;

[0266] a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, a dibenzothiophene group, a carbazole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, a naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, phenanthroline group, phenazine group, a benzimidazole group, an isobenzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, thiadiazol group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group, each substituted with at least one selected from deuterium, —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, —$Si(Q_{31})(Q_{32})(Q_{33})$, —$S(=O)_2(Q_{31})$, and —$P(=O)(Q_{31})(Q_{32})$; and

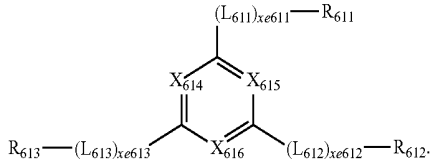
[0267] Q_{31} to Q_{33} may each independently be selected from a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0268] When xe11 in Formula 601 is two or more, two or more Ar_{601}(s) may be linked via a single bond.

[0269] In an implementation, Ar_{601} in Formula 601 may be an anthracene group.

[0270] In an implementation, the compound represented by Formula 601 may be represented by Formula 601-1:

<Formula 601-1>



[0271] In Formula 601-1,

[0272] X_{614} may be N or $C(R_{614})$, X_{615} may be N or $C(R_{615})$, X_{616} may be N or $C(R_{616})$, and at least one selected from X_{614} to X_{616} may be N,

[0273] L_{611} to L_{613} may each independently be the same as described in connection with L_{601},

[0274] xe611 to xe613 may each independently be the same as described in connection with xe1,

[0275] R_{611} to R_{613} may each independently be the same as described in connection with R_{601},

[0276] R_{614} to R_{616} may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0277] In one or more embodiments, L_{601} and L_{611} to L_{613} in Formulae 601 and 601-1 may each independently be selected from:

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

[0279] 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, and an azacarbazolyl group.

[0280] In one or more embodiments, xe1 and xe611 to xe613 in Formulae 601 and 601-1 may each independently be 0, 1, or 2.

[0281] In one or more embodiments, R_{601} and R_{611} to R_{613} in Formulae 601 and 601-1 may each independently be selected from:

[0282] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a 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;

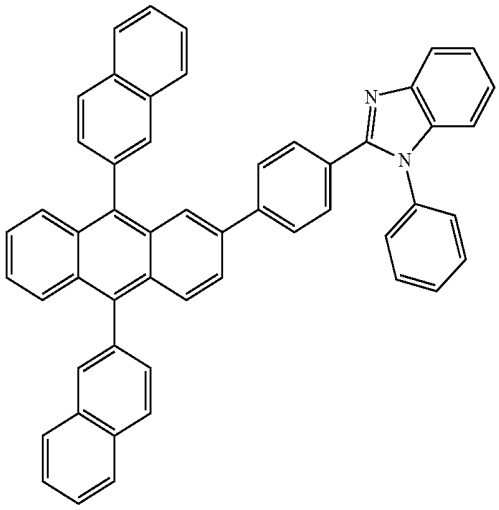
[0283] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, 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, and an azacarbazolyl group;

[0284] —$S(=O)_2(Q_{601})$ and —$P(=O)(Q_{601})(Q_{602})$; and

[0285] Q_{601} and Q_{602} may be the same as described above.

[0286] In an implementation, the electron transport region **150***c* may include at least one compound selected from Compounds ET1 to ET36:

ET1



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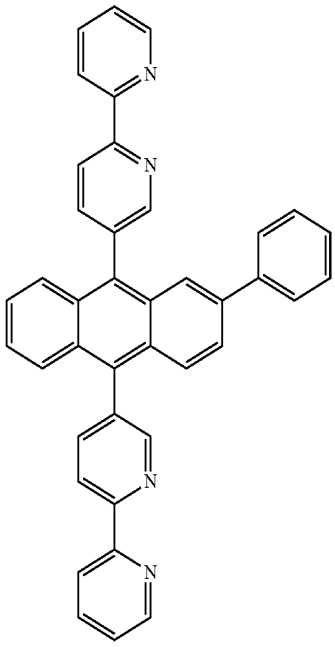

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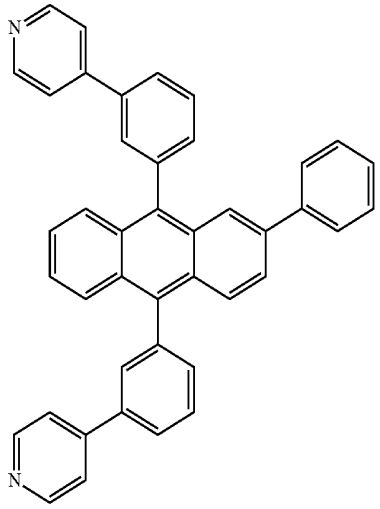

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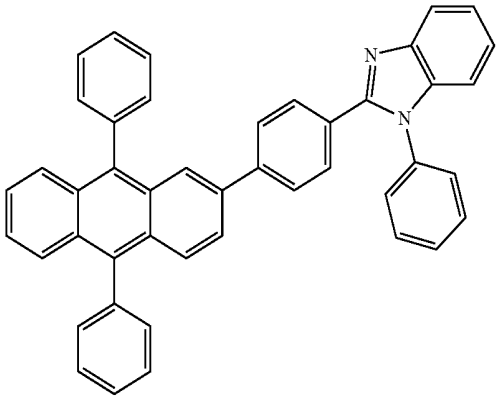

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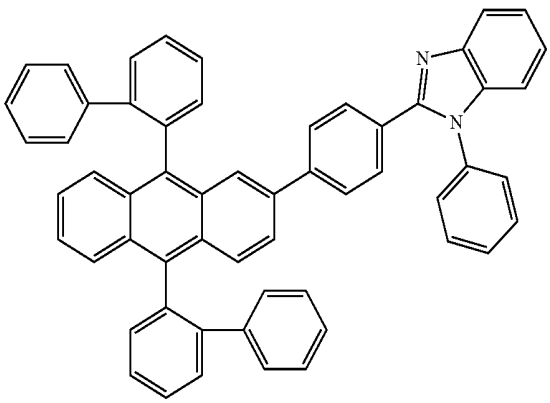

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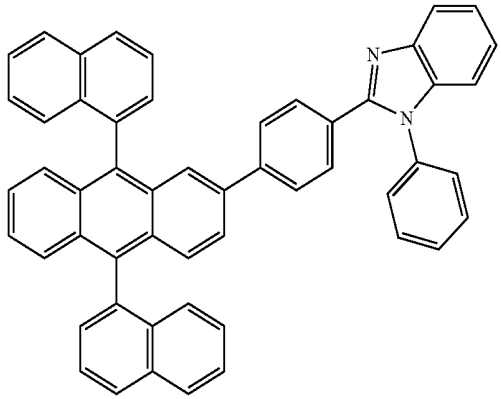
ET6



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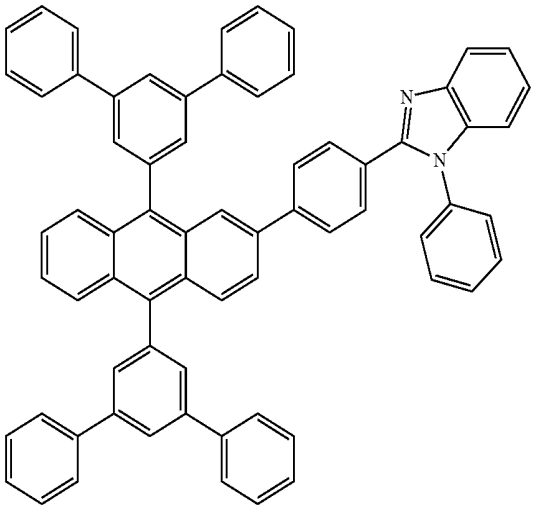

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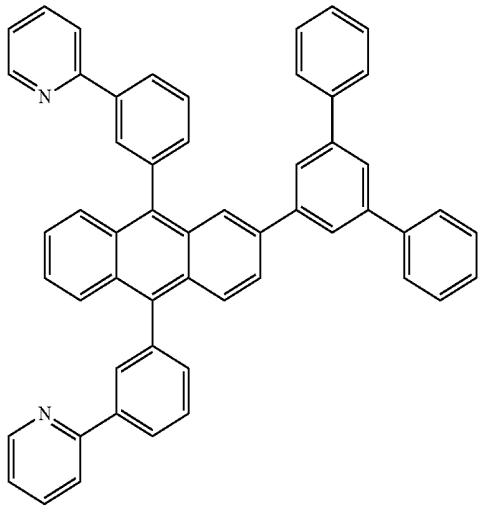

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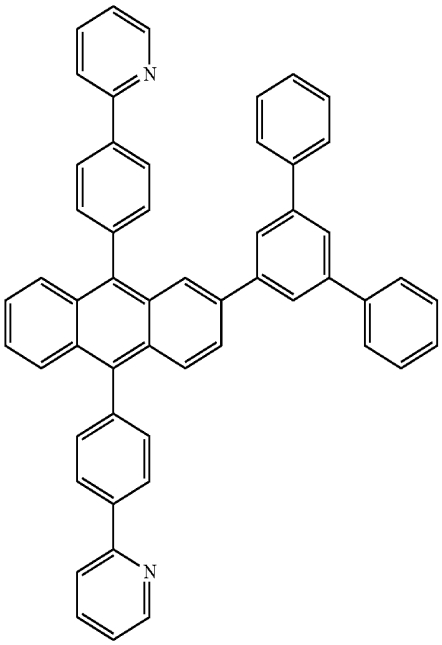

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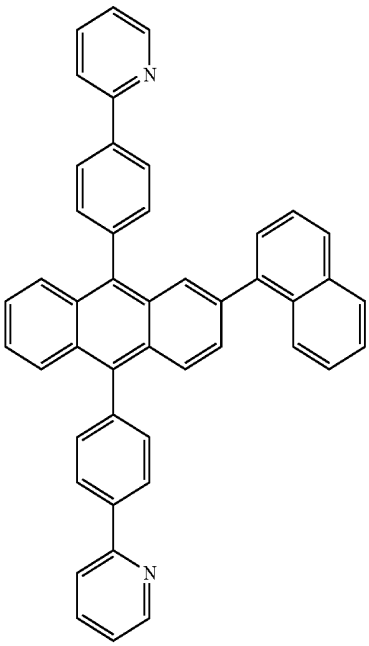

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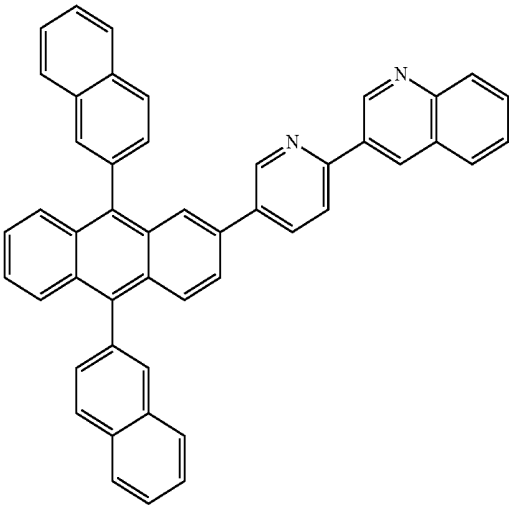

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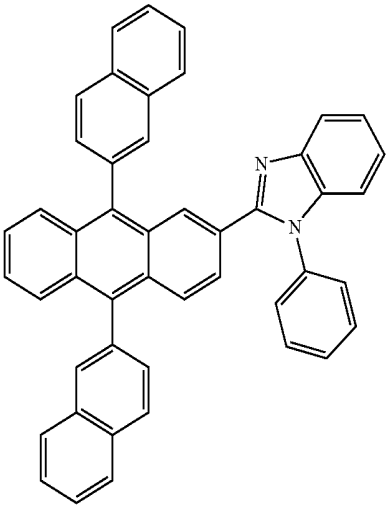

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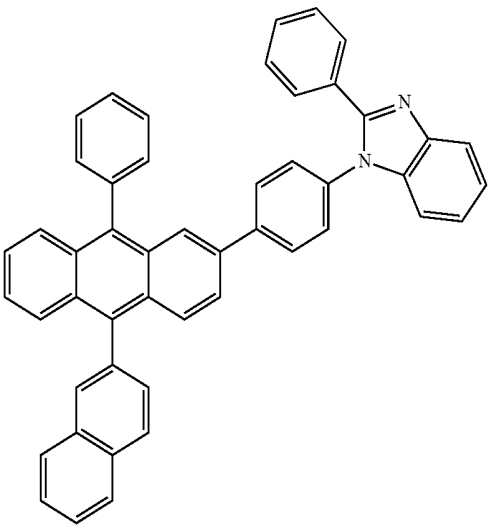

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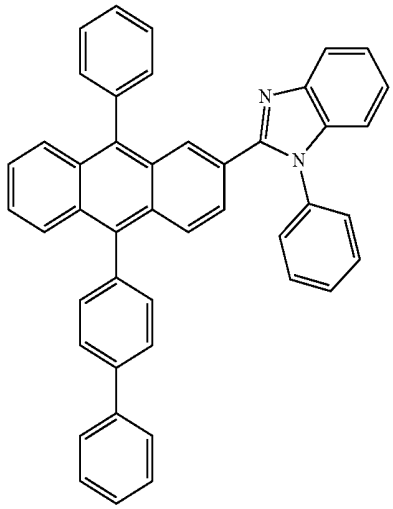

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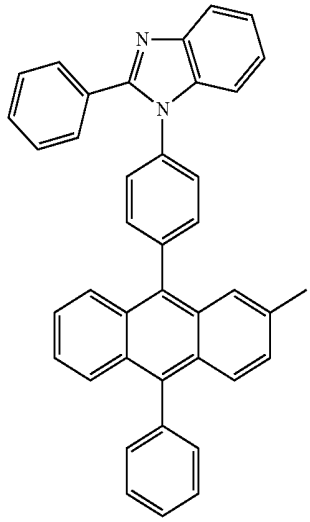

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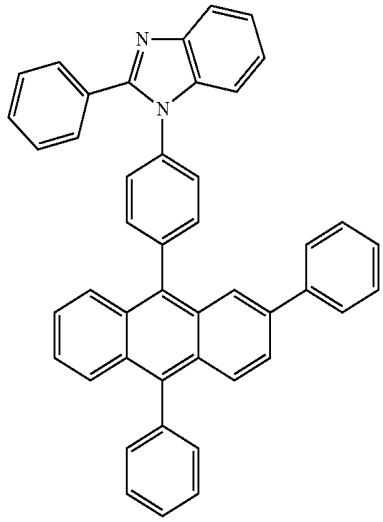

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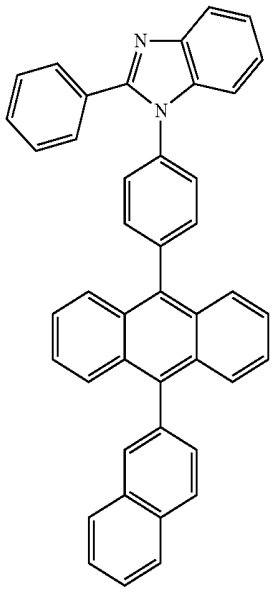

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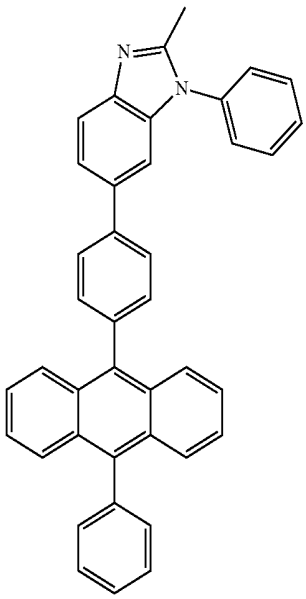

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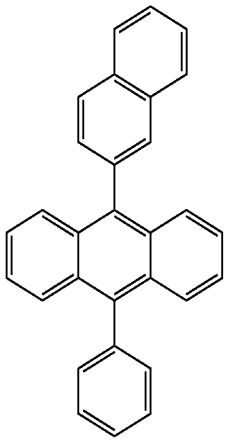

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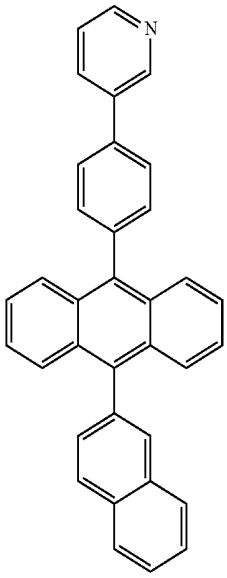

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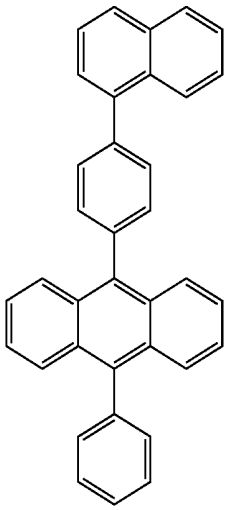

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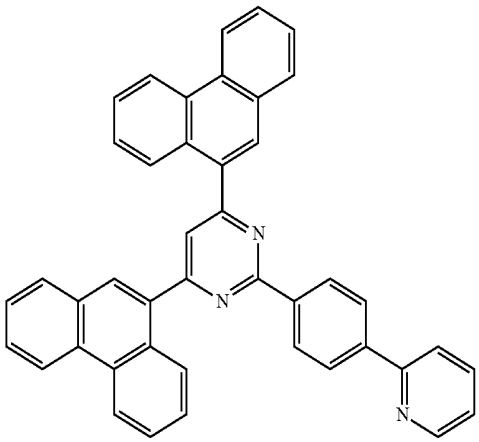

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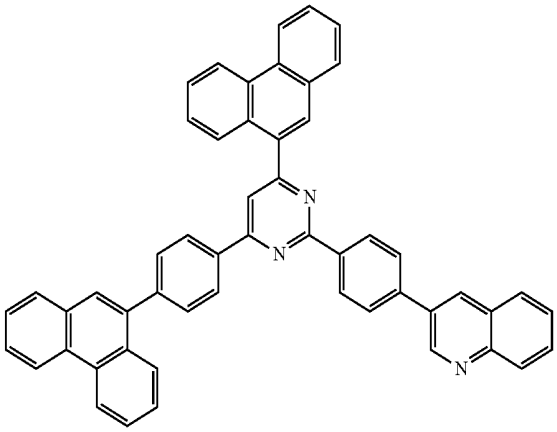
ET23



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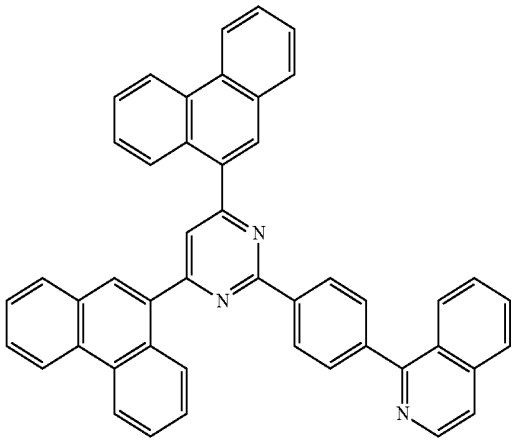

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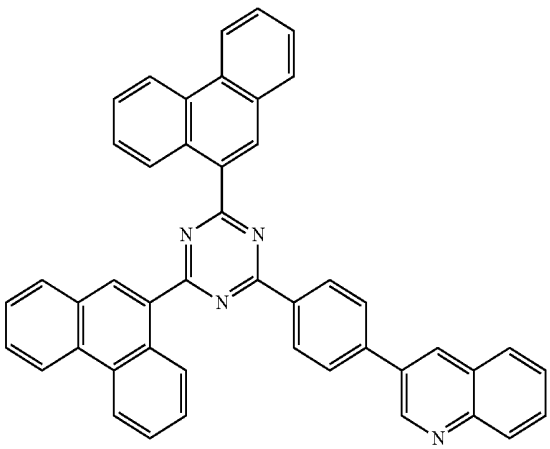

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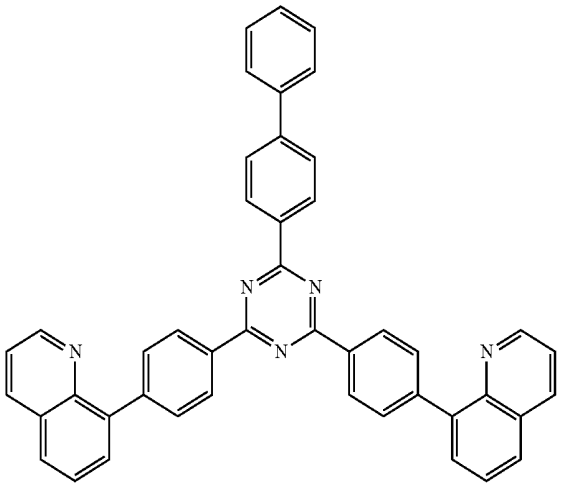
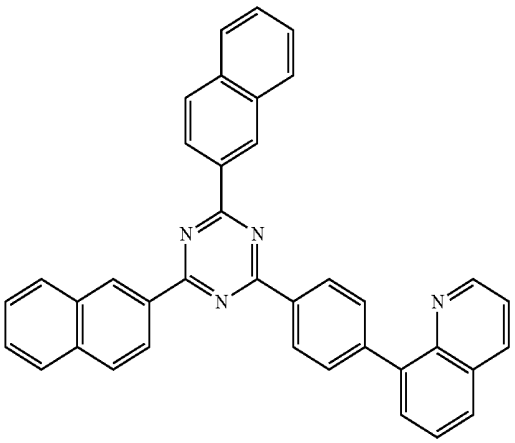


ET27



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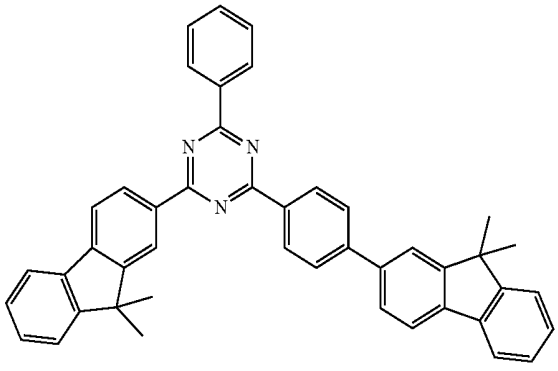

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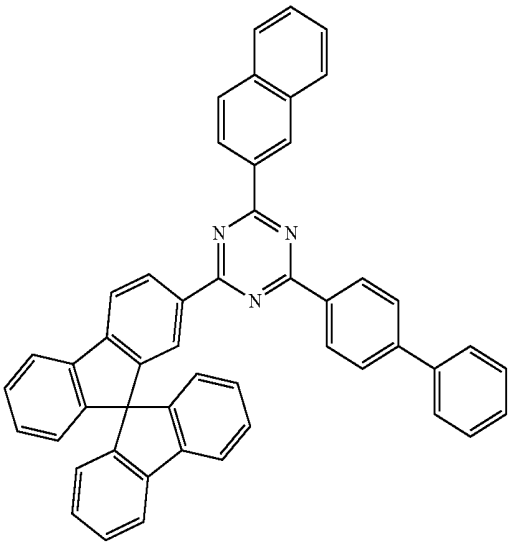

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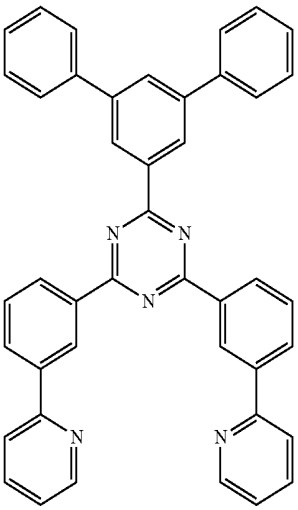

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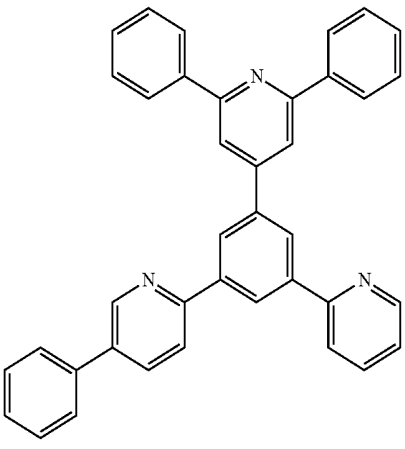

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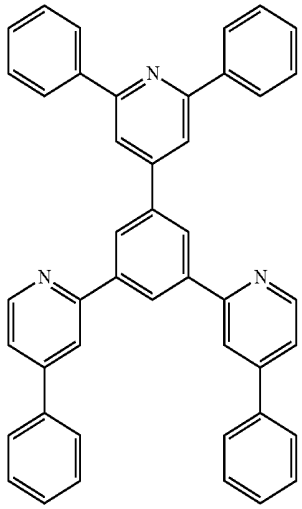
ET32



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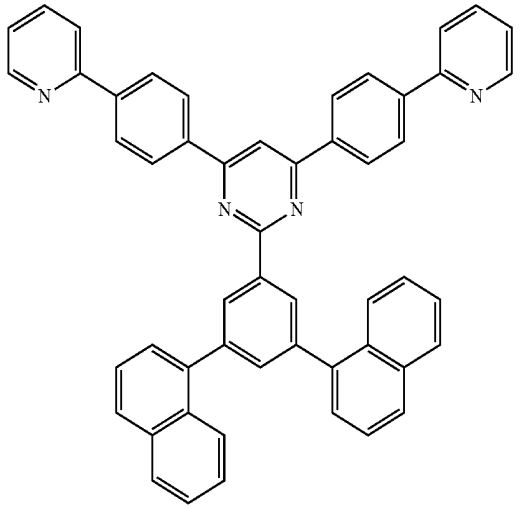

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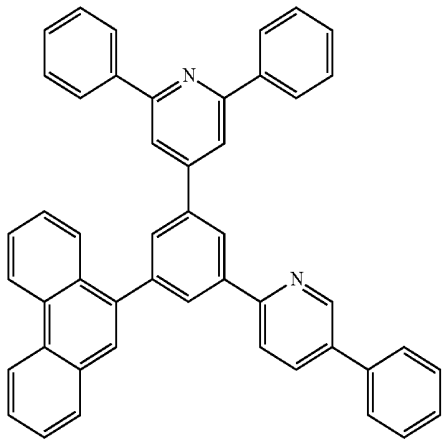

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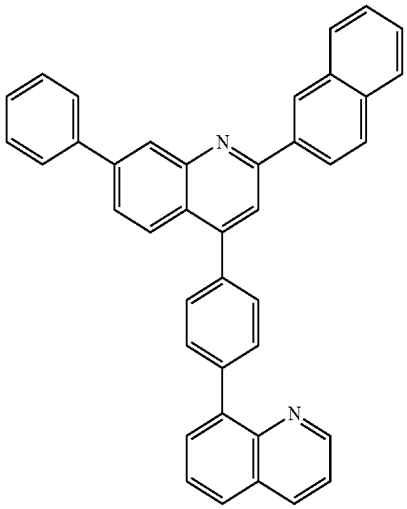
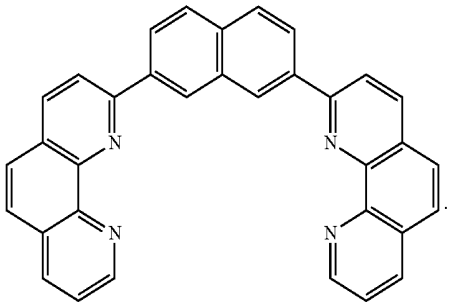
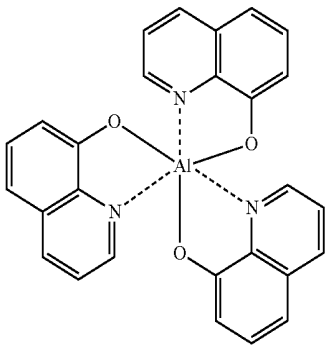
ET35



ET36



[0287] In an implementation, the electron transport region **150***c* may include at least one selected from 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP), 4,7-dphenyl-1,10-phenanthroline (Bphen), Alq_3, BAlq, 3-(biphenyl-4-yl)-5-(4-tert-butylphenyl)-4-phenyl-4H-1,2,4-triazole (TAZ), and NTAZ.



Alq_3

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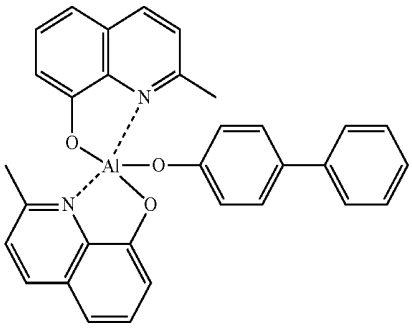
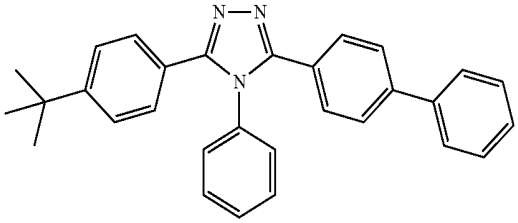
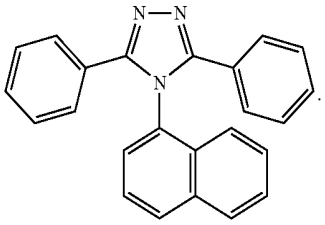


BAlq



TAZ



NTAZ

[0288] Thicknesses of the buffer layer, the hole blocking layer, and the electron control layer may each be in a range of about 20 Å to about 1,000 Å, for example, about 30 Å to about 300 Å. When the thicknesses of the buffer layer, the hole blocking layer, and the electron control layer are within these ranges, the electron blocking layer may have excellent electron blocking characteristics or electron control characteristics without a substantial increase in driving voltage.

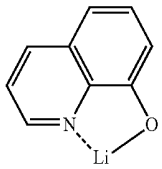
[0289] A thickness of the electron transport layer may be in a range of about 100 Å to about 1,000 Å, e.g., about 150 Å to about 500 Å. When the thickness of the electron transport layer is within the range described above, the electron transport layer may have satisfactory electron transport characteristics without a substantial increase in driving voltage.

[0290] The electron transport region **150***c* (for example, the electron transport layer in the electron transport region **150***c*) may further include, in addition to the materials described above, a metal-containing material.

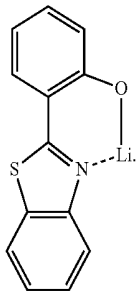
[0291] The metal-containing material may include at least one selected from alkali metal complex and alkaline earth-metal complex. The alkali metal complex may include a metal ion selected from a Li ion, a Na ion, a K ion, a Rb ion, and a Cs ion, and the alkaline earth-metal complex may include a metal ion selected from a Be ion, a Mg ion, a Ca ion, a Sr ion, and a Ba ion. A ligand coordinated with the metal ion of the alkali metal complex or the alkaline earth-metal complex may be selected from a hydroxy quinoline, a hydroxy isoquinoline, a hydroxy benzoquinoline, a hydroxy acridine, a hydroxy phenanthridine, a hydroxy 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, and a cyclopentadiene.

[0292] In an implementation, the metal-containing material may include a Li complex. The Li complex may include, for example, Compound ET-D1 (lithium quinolate, LiQ) or ET-D2.

ET-D1



ET-D2



[0293] The electron transport region **150***c* may include an electron injection layer that facilitates injection of electrons from the second electrode **190**. The electron injection layer may directly contact the second electrode **190**.

[0294] The electron injection layer may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

[0295] 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.

[0296] The alkali metal may be selected from Li, Na, K, Rb, and Cs. In an implementation, the alkali metal may be Li, Na, or Cs. In an implementation, the alkali metal may be Li or Cs.

[0297] The alkaline earth metal may be selected from Mg, Ca, Sr, and Ba.

[0298] The rare earth metal may be selected from Sc, Y, Ce, Tb, Yb, and Gd.

[0299] The alkali metal compound, the alkaline earth-metal compound, and the rare earth metal compound may be selected from oxides and halides (for example, fluorides, chlorides, bromides, or iodides) of the alkali metal, the alkaline earth-metal, and the rare earth metal.

[0300] In an implementation, the alkali metal compound may be selected from alkali metal oxides, such as Li_2O, Cs_2O, or K_2O, and alkali metal halides, such as LiF, NaF,

CsF, KF, LiI, NaI, CsI, or KI. In an implementation, the alkali metal compound may be selected from LiF, Li_2O, NaF, LiI, NaI, CsI, and KI.

[0301] In an implementation, the alkaline earth-metal compound may be selected from alkaline earth-metal oxides, such as BaO, SrO, CaO, $Ba_xSr_{1-x}O$ ($0<x<1$), or $Ba_xCa_{1-x}O$ ($0<x<1$). In an implementation, the alkaline earth-metal compound may be selected from BaO, SrO, and CaO.

[0302] In an implementation, the rare earth metal compound may be selected from YbF_3, ScF_3, ScO_3, Y_2O_3, Ce_2O_3, GdF_3, and TbF_3. In an implementation, the rare earth metal compound may be selected from YbF_3, ScF_3, TbF_3, YbI_3, ScI_3, and TbI_3.

[0303] In an implementation, the alkali metal complex, the alkaline earth-metal complex, and the rare earth metal complex may include an ion of alkali metal, alkaline earth-metal, and rare earth metal as described above, and a ligand coordinated with a metal ion of the alkali metal complex, the alkaline earth-metal complex, or the rare earth metal complex may be selected from hydroxy quinoline, hydroxy isoquinoline, hydroxy benzoquinoline, hydroxy acridine, hydroxy phenanthridine, hydroxy phenylan oxazole, hydroxy phenylthiazole, hydroxy diphenylan oxadiazole, hydroxy diphenylthiadiazol, hydroxy phenylpyridine, hydroxy phenylbenzimidazole, hydroxy phenylbenzothiazole, bipyridine, phenanthroline, and cyclopentadiene.

[0304] The electron injection layer may consist of an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare earth metal complex, or any combinations thereof, as described above. In one or more embodiments, the electron injection layer may further include an organic material. When the electron injection layer further includes an organic material, an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare earth metal complex, or any combinations thereof may be homogeneously or non-homogeneously dispersed in a matrix including the organic material.

[0305] A thickness of the electron injection layer may be in a range of about 1 Å to about 100 Å, for example, about 3 Å to about 90 Å. When the thickness of the electron injection layer is within the range described above, the electron injection layer may have satisfactory electron injection characteristics without a substantial increase in driving voltage.

[0306] [Second Electrode **190**]

[0307] The second electrode **190** may be disposed on the organic layer **150** having such a structure. The second electrode **190** may be a cathode which is an electron injection electrode, and in this regard, a material for forming the second electrode **190** may be selected from metal, an alloy, an electrically conductive compound, and a combination thereof, which have a relatively low work function.

[0308] In an implementation, the second electrode **190** may include at least one selected from lithium (Li), silver (Ag), magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), magnesium-silver (Mg—Ag), ITO, and IZO. The second electrode **190** may be a transmissive electrode, a semi-transmissive electrode, or a reflective electrode.

[0309] The second electrode **190** may have a single-layered structure, or a multi-layered structure including two or more layers.

[0310] Hereinbefore, the organic light-emitting device according to an embodiment has been described in connection with FIGS. **1** and **2**.

[0311] [Capping Layer]

[0312] In an implementation, the organic light-emitting device may include a first capping layer, a first electrode, an organic layer, and a second electrode which are sequentially stacked in this stated order. In one or more embodiments, the organic light-emitting device may include a first electrode, an organic layer, a second electrode, and a second capping layer which are sequentially stacked in this stated order. In one or more embodiments, the organic light-emitting device may include a first capping layer, a first electrode, an organic layer, a second electrode, and a second capping layer which are sequentially stacked in this stated order.

[0313] Light generated in an emission layer of an organic layer of the organic light-emitting device may be extracted toward the outside through a first electrode, which may be a semi-transmissible electrode or a transmissible electrode, and a first capping layer, or may be extracted toward the outside through a second electrode, which may be a semi-transmissible electrode or a transmissible electrode, and a second capping layer.

[0314] The first capping layer and the second capping layer may increase external luminescent efficiency according to the principle of constructive interference.

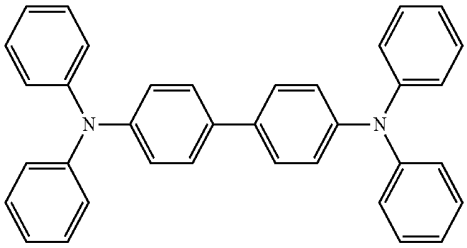
[0315] The first capping layer and the second capping layer may each independently be an organic capping layer including an organic material, an inorganic capping layer including an inorganic material, or a composite capping layer including an organic material and an inorganic material.

[0316] At least one selected from the first capping layer and the second capping layer may each independently include at least one material selected from carbocyclic compounds, heterocyclic compounds, amine-based compounds, porphyrine derivatives, phthalocyanine derivatives, a naphthalocyanine derivatives, alkali metal complexes, and alkaline earth-based complexes. The carbocyclic compound, the heterocyclic compound, and the amine-based compound may be optionally substituted with a substituent containing at least one element selected from O, N, S, Se, Si, F, Cl, Br, and I. In one or more embodiments, at least one selected from the first capping layer and the second capping layer may each independently include an amine-based compound.

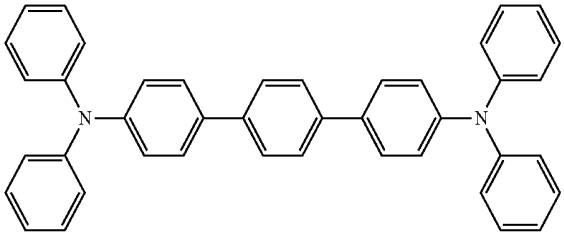
[0317] In one or more embodiments, at least one selected from the first capping layer and the second capping layer may each independently include the compound represented by Formula 201 or the compound represented by Formula 202.

[0318] In an implementation, at least one selected from the first capping layer and the second capping layer may each independently include a compound selected from Compounds HT28 to HT33 and Compounds CP1 to CP5.

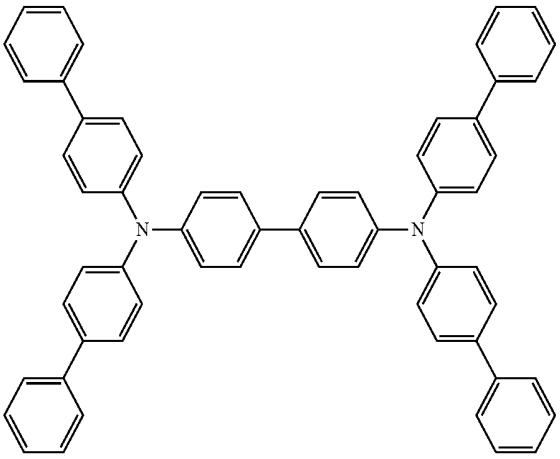
CP1



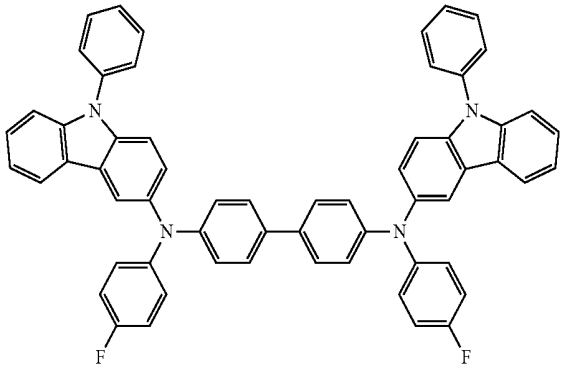
CP2



CP3



CP4



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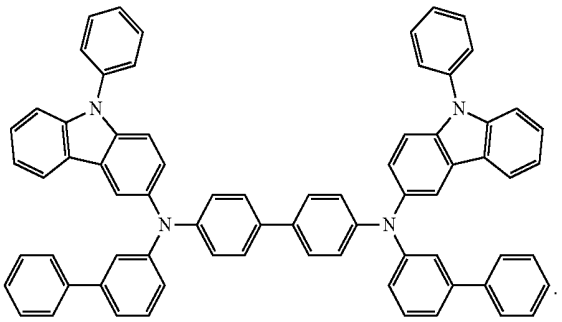
CP5



[0319] Layers constituting the hole transport region **150***a*, the emission layer **150***b*, and layers constituting the electron transport region **150***c* may be formed in a certain region by using one or more suitable methods selected from vacuum deposition, spin coating, casting, Langmuir-Blodgett (LB) deposition, ink-jet printing, laser-printing, and laser-induced thermal imaging.

[0320] When layers constituting the hole transport region **150***a*, the emission layer **150***b*, and layers constituting the electron transport region **150***c* are formed by vacuum deposition, for example, the vacuum deposition may be performed at a deposition temperature of 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 about 0.01 Å/sec to about 100 Å/sec by taking into account a material to be included in a layer to be formed, and the structure of a layer to be formed.

[0321] When layers constituting the hole transport region **150***a*, the emission layer **150***b*, and layers constituting the electron transport region **150***c* are formed by spin coating, the spin coating may be performed at a coating speed of about 2,000 rpm to about 5,000 rpm and at a heat treatment temperature of about 80° C. to about 200° C. by taking into account a material to be included in a layer to be formed, and the structure of a layer to be formed.

General Definition of Substituents

[0322] The term "C_1-C_{60} alkyl group" used herein refers to a linear or branched aliphatic saturated hydrocarbon monovalent group having 1 to 60 carbon atoms, and examples thereof include a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, a pentyl group, an iso-amyl group, and a hexyl group. The term "C_1-C_{60} alkylene group" used herein refers to a divalent group having the same structure as the C_1-C_{60} alkyl group.

[0323] The term "C_2-C_{60} alkenyl group" as used herein refers to a hydrocarbon group having at least one carbon-carbon double bond in the middle or at the terminus of the C_2-C_{60} alkyl group, and examples thereof 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.

[0324] The term "C_2-C_{60} alkynyl group" as used herein refers to a hydrocarbon group having at least one carbon-carbon triple bond in the middle or at the terminus of the C_2-C_{60} alkyl group, and examples thereof 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.

[0325] The term "C_1-C_{60} alkoxy group" as used herein refers to a monovalent group represented by —OA_{101} (wherein A_{101} is the C_1-C_{60} alkyl group), and examples thereof include a methoxy group, an ethoxy group, and an isopropyloxy group.

[0326] 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 examples thereof 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.

[0327] The term C_1-C_{10} heterocycloalkyl group used herein refers to a monovalent monocyclic group having at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom and 1 to 10 carbon atoms, and examples thereof include a 1,2,3,4-oxatriazolidinyl group, a tetrahydrofuranyl group, and a tetrahydrothiophenyl group. The term "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.

[0328] The term C_3-C_{10} cycloalkenyl group used herein refers to a monovalent monocyclic group that has 3 to 10 carbon atoms and at least one carbon-carbon double bond in the ring thereof and no aromaticity, and examples thereof 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.

[0329] 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 of the C_1-C_{10} heterocycloalkenyl group 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.

[0330] The term "C_6-C_{60} aryl group" as used herein refers to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms, and a 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 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 fused to each other.

[0331] The term "C_1-C_{60} heteroaryl group" as used herein refers to a monovalent group having a carbocyclic aromatic system that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, in addition to 1 to 60 carbon atoms. The term "C_1-C_{60} heteroarylene group" as used herein refers to a divalent group having a carbocyclic aromatic system that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, in addition to 1 to 60 carbon atoms. 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 condensed with each other.

[0332] The term "C_6-C_{60} aryloxy group" as used herein refers to —OA_{102} (wherein A_{102} is the C_6-C_{60} aryl group), and a C_6-C_{60} arylthio group used herein indicates —SA_{103} (wherein A_{103} is the C_6-C_{60} aryl group).

[0333] The term "monovalent non-aromatic condensed polycyclic group" as used herein refers to a monovalent group (for example, having 8 to 60 carbon atoms) having two or more rings condensed with each other, only carbon atoms as ring-forming atoms, and no aromaticity in its entire molecular structure. A detailed example of the monovalent non-aromatic condensed polycyclic group is a fluorenyl group. The term "divalent non-aromatic condensed polycyclic group," used herein, refers to a divalent group having the same structure as the monovalent non-aromatic condensed polycyclic group.

[0334] The term "monovalent non-aromatic condensed heteropolycyclic group" as used herein refers to a monovalent group (for example, having 1 to 60 carbon atoms) having two or more rings condensed to each other, at least one heteroatom selected from N, O, Si, P, and S, other than carbon atoms, as a ring-forming atom, and no aromaticity in its entire molecular structure. An example of the monovalent non-aromatic condensed heteropolycyclic group is a carbazolyl group. The term "divalent non-aromatic condensed heteropolycyclic group" as used herein refers to a divalent group having the same structure as the monovalent non-aromatic condensed heteropolycyclic group.

[0335] 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 benzene, a monovalent group, such as a phenyl group, or a divalent group, such as a phenylene group. In one or more embodiments, depending on the number of substituents connected to the C_5-C_{60} carbocyclic group, the C_5-C_{60} carbocyclic group may be a trivalent group or a quadrivalent group.

[0336] The term "C_1-C_{60} heterocyclic group" as 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).

[0337] At least one substituent of the substituted C_5-C_{60} carbocyclic group, substituted C_1-C_{60} heterocyclic group, substituted C_3-C_{10} cycloalkylene group, substituted C_1-C_{10} heterocycloalkylene group, substituted C_3-C_{10} cycloalkenylene group, substituted C_1-C_{10} heterocycloalkenylene group, substituted C_6-C_{60} arylene group, substituted C_1-C_{60} heteroarylene group, substituted divalent non-aromatic condensed polycyclic group, substituted divalent non-aromatic condensed heteropolycyclic group, substituted C_1-C_{60} alkyl group, substituted C_2-C_{60} alkenyl group, substituted C_2-C_{60} alkynyl group, substituted C_1-C_{60} alkoxy group, substituted C_3-C_{10} cycloalkyl group, substituted C_1-C_{10} heterocycloalkyl group, substituted C_3-C_{10} cycloalkenyl group, substituted C_1-C_{10} heterocycloalkenyl group, substituted C_6-C_{60} aryl group, substituted C_6-C_{60} aryloxy group, sub-

stituted C_6-C_{60} arylthio group, substituted C_1-C_{60} heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from:

[0338] 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, and a C_1-C_{60} alkoxy group;

[0339] 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, —$Si(Q_{11})(Q_{12})(Q_{13})$, —$N(Q_{11})(Q_{12})$, —$B(Q_{11})(Q_{12})$, —$C(=O)(Q_{11})$, —$S(=O)_2(Q_{11})$, and —$P(=O)(Q_{11})(Q_{12})$;

[0340] 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;

[0341] 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, —$Si(Q_{21})(Q_{22})(Q_{23})$, —$N(Q_{21})(Q_{22})$, —$B(Q_{21})(Q_{22})$, —$C(=O)(Q_{21})$, —$S(=O)_2(Q_{21})$, and —$P(=O)(Q_{21})(Q_{22})$;

[0342] —$Si(Q_{31})(Q_{32})(Q_{33})$, —$N(Q_{31})(Q_{32})$, —$B(Q_{31})(Q_{32})$, —$C(=O)(Q_{31})$, —$S(=O)_2(Q_{31})$, and —$P(=O)(Q_{31})(Q_{32})$; and

[0343] 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, and a terphenyl group.

[0344] 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 term "ter-Bu" or "But" used herein refers to a tert-butyl group, and the term "OMe" used herein refers to a methoxy group.

[0345] The term "biphenyl group" as used herein refers to "a phenyl group substituted with a phenyl group." In other words, the "biphenyl group" is a substituted phenyl group having a C_6-C_{60} aryl group as a substituent.

[0346] The term "terphenyl group" as used herein refers to "a phenyl group substituted with a biphenyl group." In other words, the "terphenyl group" is a phenyl group having, as a substituent, a C_6-C_{60} aryl group substituted with a C_6-C_{60} aryl group.

[0347] *, *', and *" used herein, unless defined otherwise, each refer to a binding site to a neighboring atom, e.g., in a corresponding formula.

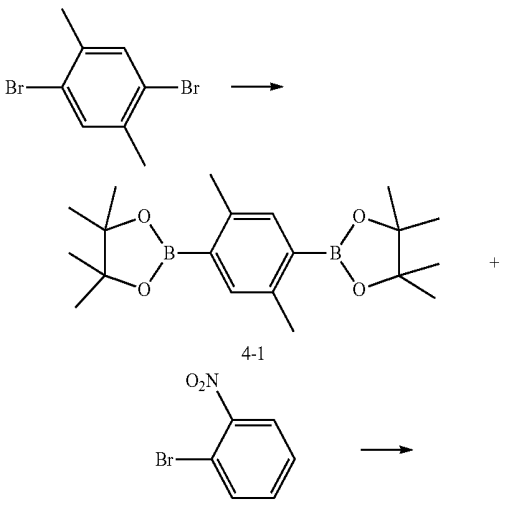
[0348] Hereinafter, a compound according to embodiments and an organic light-emitting device according to embodiments will be described in detail with reference to Synthesis Examples and Examples. The wording "B was used instead of A" used in describing Synthesis Examples refers to that an identical molar equivalent of B was used in place of A.

[0349] The following Examples and Comparative Examples are provided in order to highlight characteristics of one or more embodiments, but it will be understood that the Examples and Comparative Examples are not to be construed as limiting the scope of the embodiments, nor are the Comparative Examples to be construed as being outside the scope of the embodiments. Further, it will be understood that the embodiments are not limited to the particular details described in the Examples and Comparative Examples.

EXAMPLE

Synthesis Example 1: Synthesis of Compound 4

[0350]



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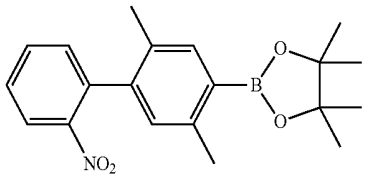

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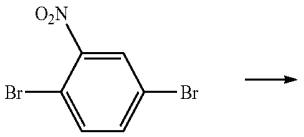

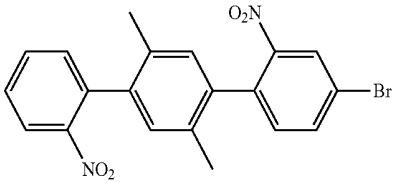

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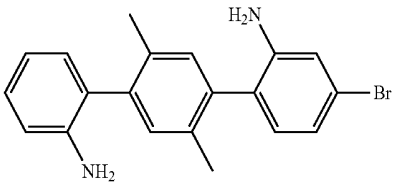

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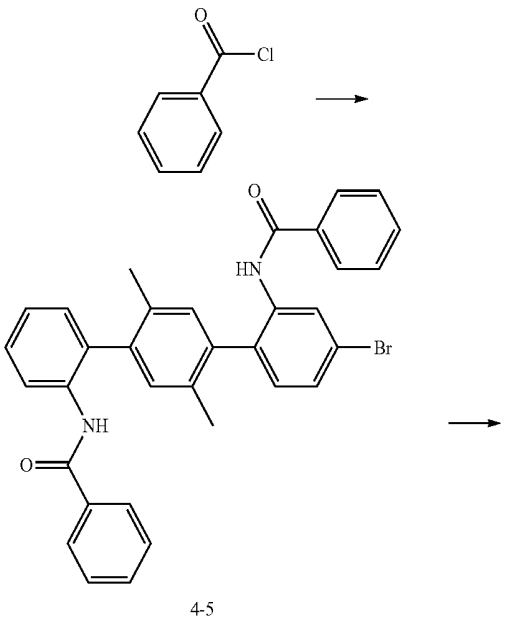

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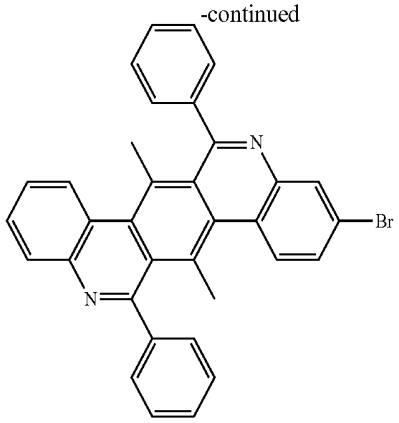
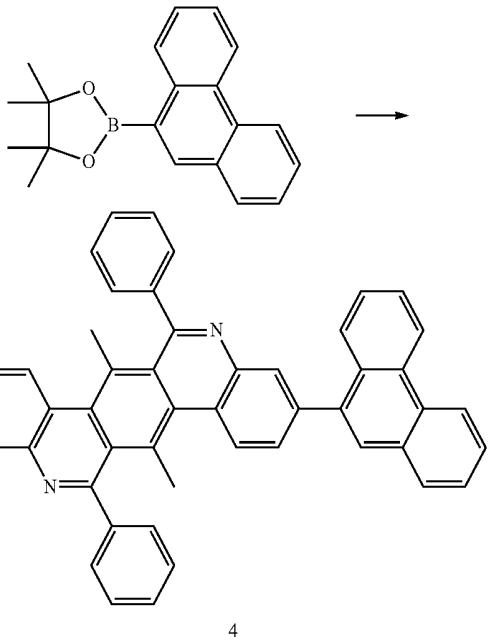


4-6



4

[0351] Synthesis of Intermediate 4-1

[0352] 2.64 g (10 mmol) of 1,4-dibromo-2,5-dimethylbenzene was dissolved in 30 mL of tetrahydrofuran (THF), and 8 mL of n-butyllithium (2.5 M in hexane) was added thereto at a temperature of −78° C. After 1 hour, 4.08 mL (20 mmol) of 2-isopropoxy-4,4,5,5-tetramethyl-1,3,2-dioxaborolane was added thereto at the same temperature. The resultant mixture was stirred at ambient temperature for 5 hours. Then, water was added to the resultant mixture, and washing thereof was performed three times using 30 mL of diethyl ether. A washed diethyl ether layer was dried using $MgSO_4$ and then dried under reduced pressure. A product obtained therefrom was separated and purified by silica gel column chromatography to obtain 2.69 g (yield: 75%) of Intermediate 4-1 as a white solid. The obtained compound was identified by LC-MS. $C_{20}H_{32}B_2O_4$: M^+ 328.1.

[0353] Synthesis of Intermediate 4-2

[0354] 5.37 g (15.0 mmol) of Intermediate 4-1, 2.02 g (10.0 mmol) of 1-bromo-2-nitrobenzene, 0.58 g (0.5 mmol) of $Pd(PPh_3)_4$, 0.16 g (0.5 mmol) of tetrabutylammonium bromide (TBAB), and 3.18 g (30.0 mmol) of Na_2CO_3 were dissolved in 60 mL of a mixed solvent of toluene/ethanol/H_2O (volume ratio 3/3/1) and stirred at a temperature of 80°

C. for 16 hours. The reaction solution was cooled to ambient temperature, and an extraction process was performed thereon three times using 60 mL of water and 60 mL of diethyl ether. Then, an organic layer obtained therefrom was dried using magnesium sulfate, and a solvent was evaporated therefrom. The residue obtained therefrom was separated and purified by silica gel column chromatography to obtain 2.82 g (yield: 80%) of Intermediate 4-2. The obtained compound was identified by LC-MS. $C_{20}H2_4BNO_4$: M^+ 353.1.

[0355] Synthesis of Intermediate 4-3

[0356] 3.53 g (10.0 mmol) of Intermediate 4-2, 5.62 g (20.0 mmol) of 1,4-dibromo-2-nitrobenzene, 0.58 g (0.5 mmol) of $Pd(PPh_3)_4$, 0.16 g (0.5 mmol) of TBAB, and 3.18 g (30.0 mmol) of Na_2CO_3 were dissolved in 60 mL of a mixed solvent of toluene/ethanol/H_2O (volume ratio 3/3/1) and stirred at a temperature of 80° C. for 16 hours. The reaction solution was cooled to ambient temperature, and an extraction process was performed thereon three times using 60 mL of water and 60 mL of diethyl ether. Then, an organic layer obtained therefrom was dried using magnesium sulfate, and a solvent was evaporated therefrom. The residue obtained therefrom was separated and purified by silica gel column chromatography to obtain 2.99 g (yield: 70%) of Intermediate 4-3. The obtained compound was identified by LC-MS. $C_{20}H_{15}BrN_2O_4$: M^+ 426.0.

[0357] Synthesis of Intermediate 4-4

[0358] 4.27 g (10.0 mmol) of Intermediate 4-3, 4.75 g (40 mmol) of tin, and 10 mL (100 mmol, conc. 36.5%) of HCl were dissolved in 60 mL of ethanol and stirred at a temperature of 100° C. for 8 hours. The reaction solution was cooled to ambient temperature and filtered under reduced pressure to obtain a filtrate. 3 g of sodium hydroxide was dissolved in 10 mL of water and added to the filtrate, and an extraction process was performed thereon three times using 60 mL of water and 60 mL of dichloromethane. An organic layer obtained therefrom was dried using magnesium sulfate, and a solvent was evaporated therefrom. The residue obtained therefrom was separated and purified by silica gel column chromatography to obtain 3.30 g (yield: 90%) of Intermediate 4-4. The obtained compound was identified by LC-MS. $C_{20}H_{19}BrN_2$: M^+ 366.0.

[0359] Synthesis of Intermediate 4-5

[0360] 3.67 g (10.0 mmol) of Intermediate 4-4 and 13.9 mL (100 mmol) of triethylamine were dissolved in 60 mL of THF, and 3.49 mL (30 mmol) of benzoyl chloride was added thereto at a temperature of 0° C. The resultant mixture was stirred at ambient temperature for 5 hours. Then, water was added to the resultant mixture, and washing thereof was performed three times using 30 mL of diethyl ether. A washed diethyl ether layer was dried using $MgSO_4$ and then dried under reduced pressure. A product obtained therefrom was separated and purified by silica gel column chromatography to obtain 4.32 g (yield: 75%) of Intermediate 4-5 as a white solid. The obtained compound was identified by LC-MS. $C_{34}H_{27}BrN_2O_2$: M^+ 574.1.

[0361] Synthesis of Intermediate 4-6

[0362] 5.76 g (10 mmol) of Intermediate 4-5 and 14.2 g (50 mmol) of phosphorus pentoxide were dissolved in 10 mL of $POCl_3$ and stirred at a temperature of 105° C. for 48 hours. The reaction solution was cooled to ambient temperature and quenched using NaOH. Then, an extraction process was performed thereon three times using 60 mL of water and 60 mL of dichloromethane. An organic layer obtained therefrom was dried using magnesium sulfate, and a solvent was evaporated therefrom. The residue obtained therefrom was separated and purified by silica gel column chromatography to obtain 3.23 g (yield: 60%) of Intermediate 4-6. The obtained compound was identified by LC-MS. $C_{34}H_{23}BrN_2$: M^+ 538.1.

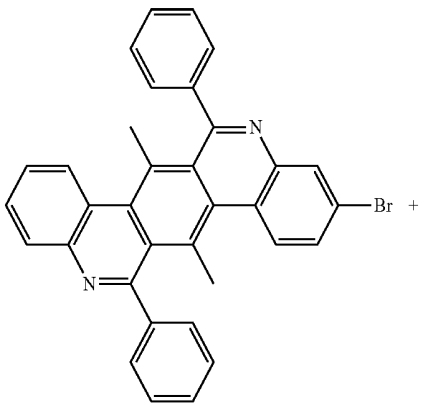
[0363] Synthesis of Compound 4

[0364] 5.39 g (10 mmol) of Intermediate 4-6, 3.04 g (10 mmol) of 4,4,5,5-tetramethyl-2-(phenanthren-9-yl)-1,3,2-dioxaborolane, 0.58 g (0.5 mmol) of $Pd(PPh_3)_4$ (tetrakis (triphenylphosphine)palladium), and 4.14 g (30 mmol) of K_2CO_3 were dissolved in 60 mL of a mixed solvent of THF/H_2O (volume ratio of 2/1) and stirred at a temperature of 80° C. for 16 hours. The reaction solution was cooled to ambient temperature. Then, 40 mL of water was added to the reaction solution, and an extraction process was performed thereon three times using 50 mL of ethyl ether. An organic layer obtained therefrom was dried using magnesium sulfate, and a solvent was evaporated therefrom. The residue obtained therefrom was separated and purified by silica gel column chromatography to obtain 4.14 g (yield: 65%) of Compound 4. The obtained Compound was identified by MS/FAB and ^1H NMR. $C_{48}H_{32}N_2$: M^+ cal.: 636.26, found: 636.16.

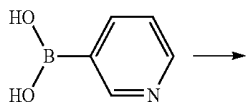
[0365] ^1H NMR (400 MHz, $CDCl_3$) δ (ppm) 8.93 (d, 1H), 8.64 (d, 1H), 8.55 (d, 1H), 8.42 (d, 1H), 8.23 (s, 1H), 8.07-7.77 (m, 10H), 7.69-7.50 (m, 10H), 7.13 (t, 1H), 2.99 (s, 3H), 2.97 (s, 3H).

Synthesis Example 2: Synthesis of Compound 9

[0366]



4-6



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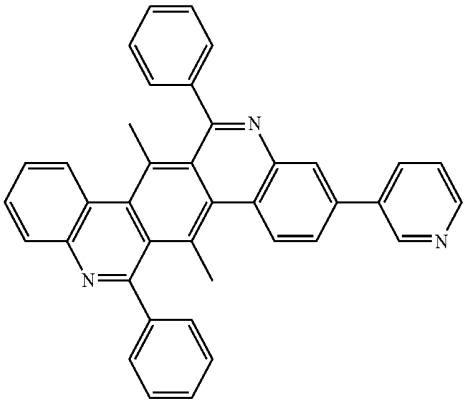


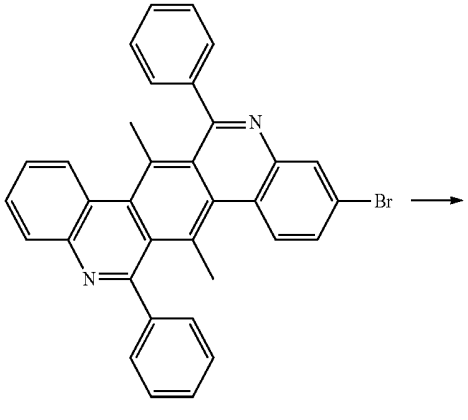
9

[0367] 5.39 g (10 mmol) of Intermediate 4-6, 1.23 g (10 mmol) of pyridin-3-ylboronic acid, 0.58 g (0.5 mmol) of $Pd(PPh_3)_4$ (tetrakis(triphenylphosphine)palladium), and 4.14 g (30 mmol) of K_2CO_3 were dissolved in 60 mL of a mixed solvent of THF/H_2O (volume ratio of 2/1) and stirred at a temperature of 80° C. for 16 hours. The reaction solution was cooled to ambient temperature. Then, 40 mL of water was added to the reaction solution, and an extraction process was performed thereon three times using 50 mL of ethyl ether. An organic layer collected therefrom was dried using magnesium sulfate, and a solvent was evaporated therefrom. The residue obtained therefrom was separated and purified by silica gel column chromatography to obtain 2.95 g (yield: 55%) of Compound 9. The obtained compound was identified by MS/FAB and 11 NMR. $C_{39}H_{27}N_3$: M^+ cal.: 537.22, found: 537.12.

[0368] ^1H NMR (400 MHz, $CDCl_3$) δ (ppm) 9.07 (s, 1H), 8.93 (d, 1H), 8.66-8.60 (m, 2H), 8.17-7.85 (m, 9H), 7.67-7.52 (m, 8H), 2.99 (s, 3H), 2.97 (s, 3H).

Synthesis Example 3: Synthesis of Compound 18

[0369]



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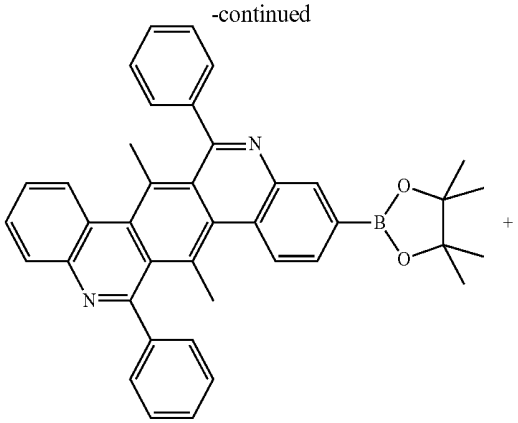
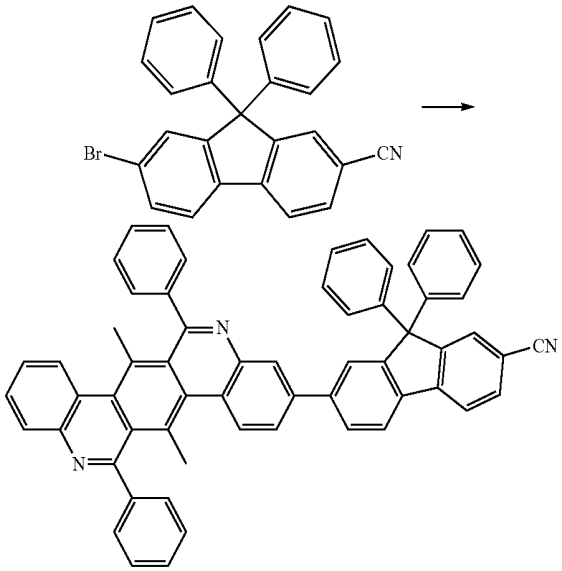


18-1



18

[0370] Synthesis of Intermediate 18-1

[0371] 5.39 g (10 mmol) of Intermediate 4-6 was dissolved in 30 mL of THF, and 4 mL of n-butyllithium (2.5 M in hexane) was added thereto at a temperature of −78° C. After 1 hour, 2.04 mL (10 mmol) of 2-isopropoxy-4,4,5,5-tetramethyl-1,3,2-dioxaborolane was added thereto at the same temperature. The resultant mixture was stirred at ambient temperature for 5 hours. Then, water was added to the resultant mixture, and washing thereof was performed three times using 30 mL of diethyl ether. A layer of the diethyl ether used for the washing was dried using $MgSO_4$ and then dried under reduced pressure. A product obtained therefrom was separated and purified by silica gel column chromatography to obtain 4.11 g (yield: 70%) of Intermediate 18-1. The obtained compound was identified by LC-MS. $C_{40}H_{35}BN_2O_2$: M^+ 586.2.

[0372] Synthesis of Compound 18

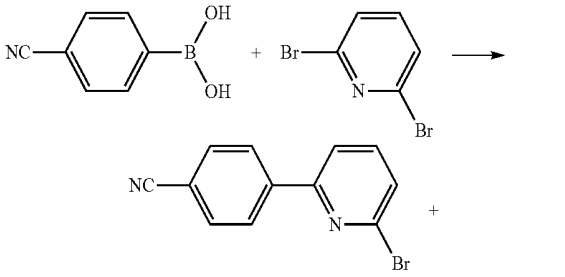
[0373] 5.86 g (10 mmol) of Intermediate 18-1, 4.22 g (10 mmol) of 7-bromo-9,9-diphenyl-9H-fluorene-2-carbonitrile, 0.58 g (0.5 mmol) of $Pd(PPh_3)_4$ (tetrakis(triphenylphosphine)palladium), and 4.14 g (30 mmol) of K_2CO_3 were dissolved in 60 mL of a mixed solution of THF/H_2O (volume ratio of 2/1) and stirred at a temperature of 80° C. for 16 hours. The reaction solution was cooled to ambient

temperature. Then, 40 mL of water was added to the reaction solution, and an extraction process was performed thereon three times using 50 mL of ethyl ether. An organic layer collected therefrom was dried using magnesium sulfate, and a solvent was evaporated therefrom. The residue obtained therefrom was separated and purified by silica gel column chromatography to obtain 5.21 g (yield: 65%) of Compound 18. The obtained compound was identified by MS/FAB and ^{1}H NMR. $C_{60}H_{39}N_3$: M^+ cal.: 801.31, found: 801.21.

[0374] ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 8.93 (d, 1H), 8.43 (d, 1H), 8.19 (s, 1H), 8.06 (d, 1H), 7.99-7.83 (m, 7H), 7.74-7.55 (m, 10H), 7.39-7.28 (m, 6H), 7.15-7.06 (m, 6H), 2.99 (s, 3H), 2.97 (s, 3H).

Synthesis Example 4: Synthesis of Compound 43

[0375]



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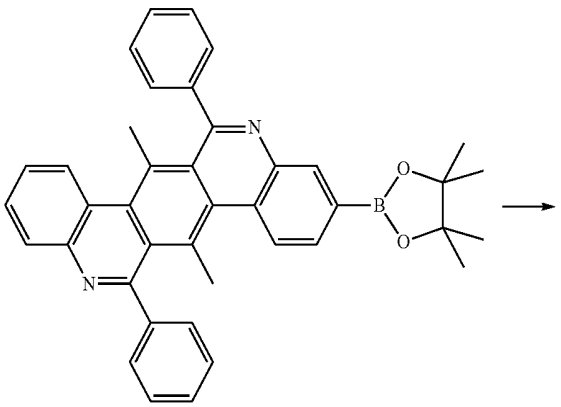

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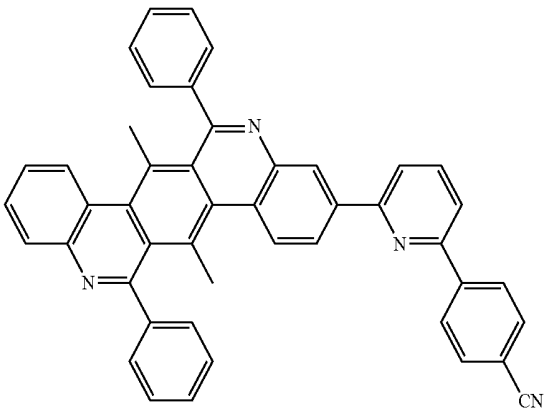


43

[0376] Synthesis of Intermediate 43-1

[0377] 1.47 g (10 mmol) of 4-cyanophenylboronic acid, 3.56 g (15 mmol) of 2,6-dibromopyridine, 0.58 g (0.5 mmol) of $Pd(PPh_3)_4$ (tetrakis(triphenylphosphine)palladium), and 4.14 g (30 mmol) of K_2CO_3 were dissolved in 60 mL of a mixed solvent of THF/H_2O (volume ratio of 2/1) and stirred at a temperature of 80° C. for 16 hours. The reaction solution was cooled to ambient temperature. Then, 40 mL of water was added to the reaction solution, and an extraction process was performed thereon three times using 50 mL of ethyl ether. An organic layer collected therefrom was dried using magnesium sulfate, and a solvent was evaporated therefrom. The residual obtained therefrom was separated and purified by silica gel column chromatography to obtain 1.81 g (yield: 70%) of Intermediate 43-1. The obtained compound was identified by LC-MS. $C_{12}H7BrN_2$: M^+ 257.9.

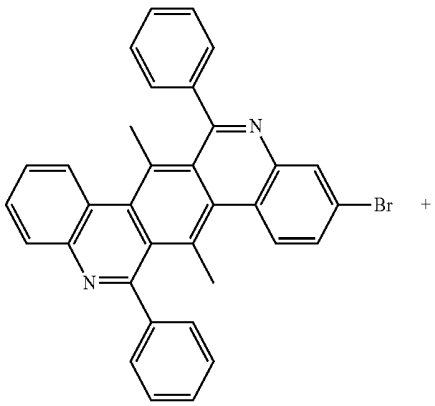
[0378] Synthesis of Compound 43

[0379] 2.59 g (10 mmol) of Intermediate 43-1, 5.86 g (10 mmol) of Intermediate 18-1, 0.58 g (0.5 mmol) of $Pd(PPh_3)_4$ (tetrakis(triphenylphosphine)palladium), and 4.14 g (30 mmol) of K_2CO_3 were dissolved in 60 mL of a mixed solvent of THF/H_2O (volume ratio of 2/1) and stirred at a temperature of 80° C. for 16 hours. The reaction solution was cooled to ambient temperature. Then, 40 mL of water was added to the reaction solution, and an extraction process was performed thereon three times using 50 mL of ethyl ether. An organic layer collected therefrom was dried using magnesium sulfate, and a solvent was evaporated therefrom. The residue was separated and purified by silica gel column chromatography to obtain 4.15 g (yield: 65%) of Compound 43. The obtained compound was identified by MS/FAB and ^{1}H NMR. $C_{46}H_{30}N_4$: M^+ cal.: 638.25, found: 638.15.

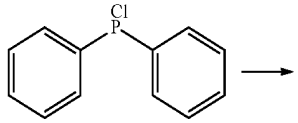
[0380] ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 8.93 (d, 1H), 8.84 (d, 1H), 8.64 (s, 1H), 8.44 (d, 1H), 8.33 (d, 2H), 8.06 (d, 1H), 7.99-7.85 (m, 6H), 7.77-7.60 (m, 11H), 2.99 (s, 3H), 2.97 (s, 3H).

Synthesis Example 5: Synthesis of Compound 45

[0381]



4-6



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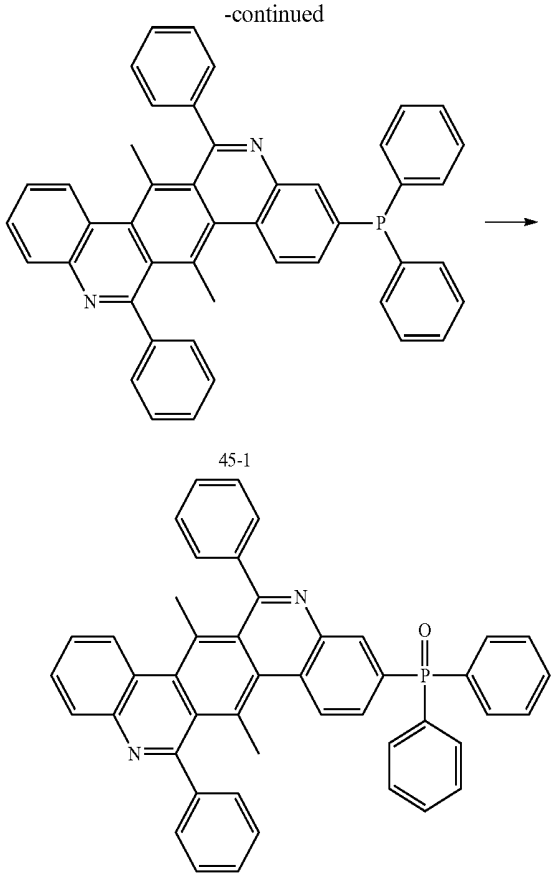


45-1

45

[0382] Synthesis of Intermediate 45-1

[0383] 5.39 g (10 mmol) of Intermediate 4-6 was dissolved in 30 mL of THF, and 4 mL of n-butyl lithium (2.5 M in hexane) was added thereto at a temperature of −78° C. After 1 hour, 1.98 mL (11 mmol) of chlorodiphenylphosphine was added thereto at the same temperature. The resultant mixture was stirred at ambient temperature for 5 hours. Then, water was added to the resultant mixture, and washing thereof was performed three times using 30 mL of diethyl ether. A layer of the diethyl ether used for the washing was dried using $MgSO_4$ and then dried under reduced pressure. A product obtained therefrom was separated and purified by silica gel column chromatography to obtain 4.52 g (yield: 70%) of Intermediate 45-1. The obtained compound was identified by LC-MS. $C_{46}H_{33}N_2P$: M^+ 644.2.

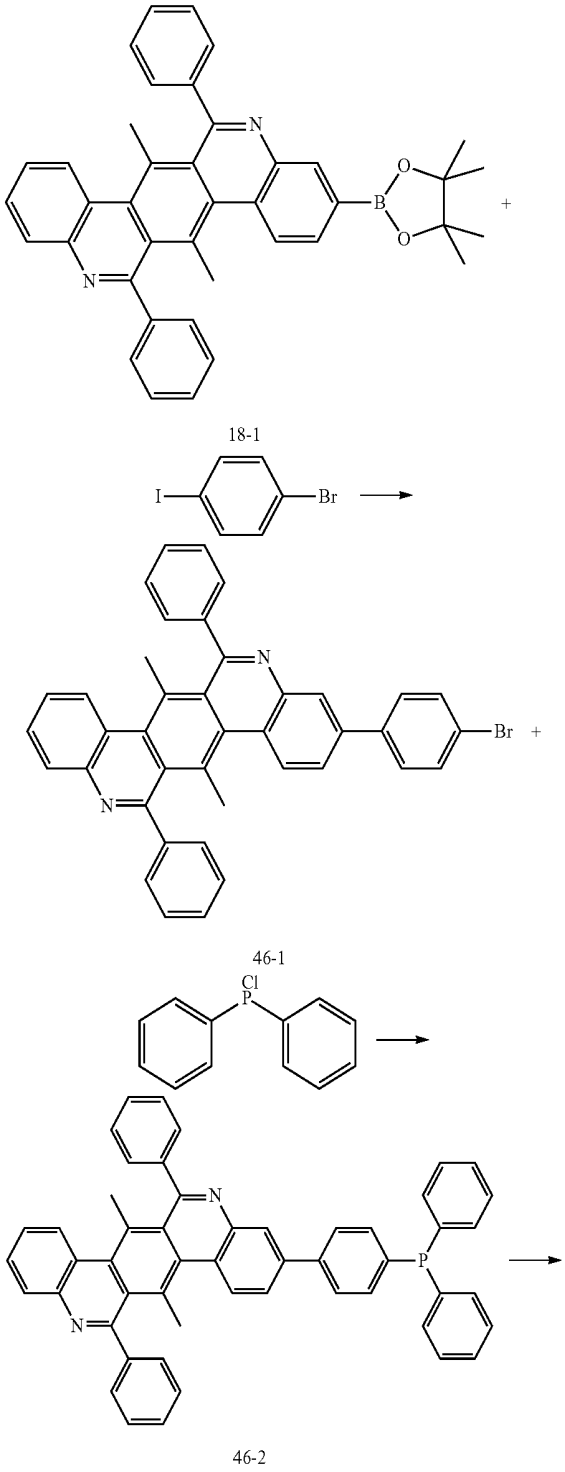
[0384] Synthesis of Compound 45

[0385] 6.45 g (10 mmol) of Intermediate 45-1 was dissolved in 50 mL of dichloromethane, and 2 mL of hydrogen peroxide (aqueous solution, 50 wt %) was added thereto. Then, the mixed solution was stirred at ambient temperature for 2 hours. Then, 50 mL of water was added to the mixed solution, and an extraction process was performed thereon three times using 50 mL of dichloromethane. An organic layer collected therefrom was dried by using magnesium sulfate, and a solvent was evaporated therefrom. The residue obtained therefrom was separated and purified by silica gel column chromatography to obtain 6.28 g (yield: 95%) of Compound 45. The obtained compound was identified by MS/FAB and ^1H NMR. $C_{46}H_{33}N_2OP$: M^+ cal.: 660.23, found: 660.13.

[0386] ^1H NMR (400 MHz, $CDCl_3$) δ (ppm) 8.93 (d, 1H), 8.55-8.48 (m, 2H), 8.07-7.60 (m, 18H), 7.52-7.39 (m, 6H), 2.99 (s, 3H), 2.97 (s, 3H).

Synthesis Example 6: Synthesis of Compound 46

[0387]

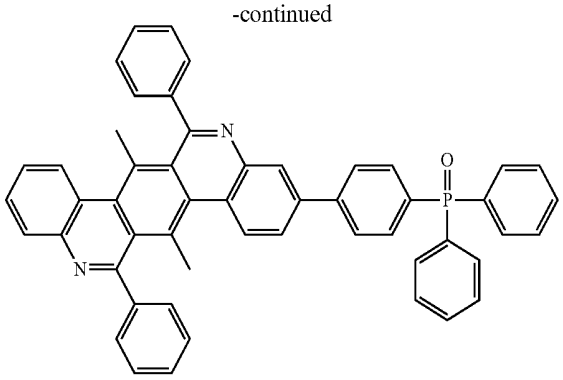


18-1

46-1

46-2

-continued



46

[0388] Synthesis of Intermediate 46-1

[0389] 5.86 g (10 mmol) of Intermediate 18-1, 4.25 g (15 mmol) of 1-bromo-4-iodobenzene, 0.58 g (0.5 mmol) of $Pd(PPh_3)_4$ (tetrakis(triphenylphosphine)palladium), and 4.14 g (30 mmol) of K_2CO_3 were dissolved in 60 mL of a mixed solvent of THF/H_2O (volume ratio of 2/1) and stirred at a temperature of 80° C. for 16 hours. The reaction solution was cooled to ambient temperature. Then, 40 mL of water was added to the reaction solution, and an extraction process was performed thereon three times using ethyl ether. An organic layer collected therefrom was dried by using magnesium sulfate, and a solvent was evaporated therefrom. The residue obtained therefrom was separated and purified by silica gel column chromatography to obtain 4.62 g (yield: 75%) of Compound 46-1. The obtained compound was identified by LC-MS. $C_{40}H2_7BrN_2$: M^+ 614.1.

[0390] Synthesis of Intermediate 46-2

[0391] 6.16 g (10 mmol) of Intermediate 46-1 was dissolved in 30 mL of THF, and 4 mL of n-butyl lithium (2.5 M in hexane) was added thereto at a temperature of −78° C. After 1 hour, 1.98 mL (11 mmol) of chlorodiphenylphosphine was added thereto at the same temperature. The resultant mixture was stirred at ambient temperature for 5 hours. Then, water was added to the resultant mixture, and washing thereof was performed three times using 30 mL of diethyl ether. A layer of the diethyl ether used for the washing was dried using $MgSO_4$ and then dried under reduced pressure. A product obtained therefrom was separated and purified by silica gel column chromatography to obtain 5.05 g (yield: 70%) of Intermediate 46-2. The obtained compound was identified by LC-MS. $C_{52}H_{37}N_2P$: M^+ 720.2.

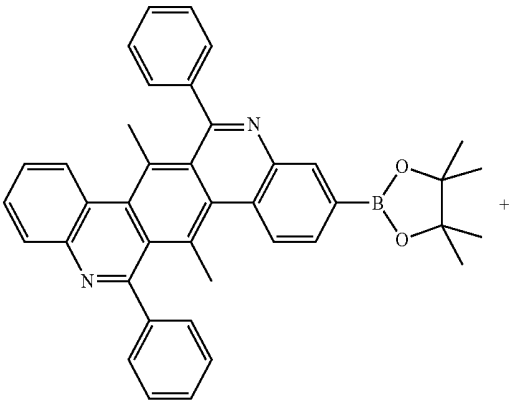
[0392] Synthesis of Compound 46

[0393] 7.21 g (10 mmol) of Intermediate 46-2 was dissolved in 50 mL of dichloromethane and 2 mL of hydrogen peroxide (aqueous solution, 50 wt %). Then, the resultant mixture was stirred at ambient temperature for 2 hours. Then, 50 mL of water was added to the resultant mixture, and an extraction process was performed thereon three times using 50 mL of dichloromethane. An organic layer collected therefrom was dried using magnesium sulfate, and a solvent was evaporated therefrom. The residue obtained therefrom was separated and purified by silica gel column chromatography to obtain 7.00 g (yield: 95%) of Compound 46. The obtained compound was identified by MS/FAB and ^1H NMR. $C_{52}H_{37}N_2OP$: M^+ cal.: 736.26, found: 736.16.

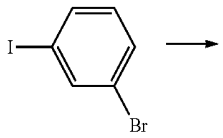
[0394] ^1H NMR (400 MHz, $CDCl_3$) δ (ppm) 8.93 (d, 1H), 8.57 (d, 1H), 8.06 (d, 1H), 8.00-7.60 (m, 22H), 7.52-7.39 (m, 6H), 2.99 (s, 3H), 2.97 (s, 3H).

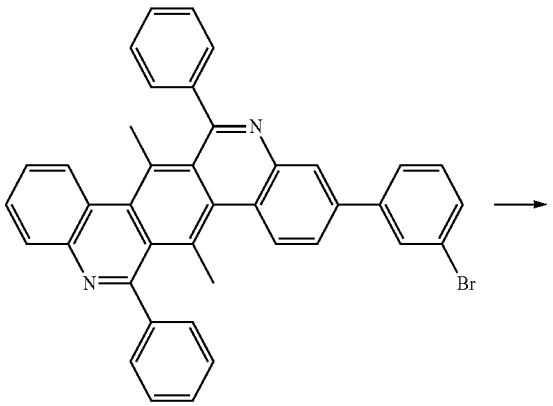
Synthesis Example 7: Synthesis of Compound 51

[0395]

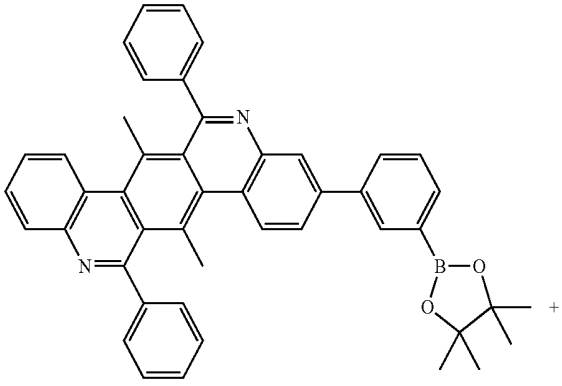


18-1





51-1



51-2

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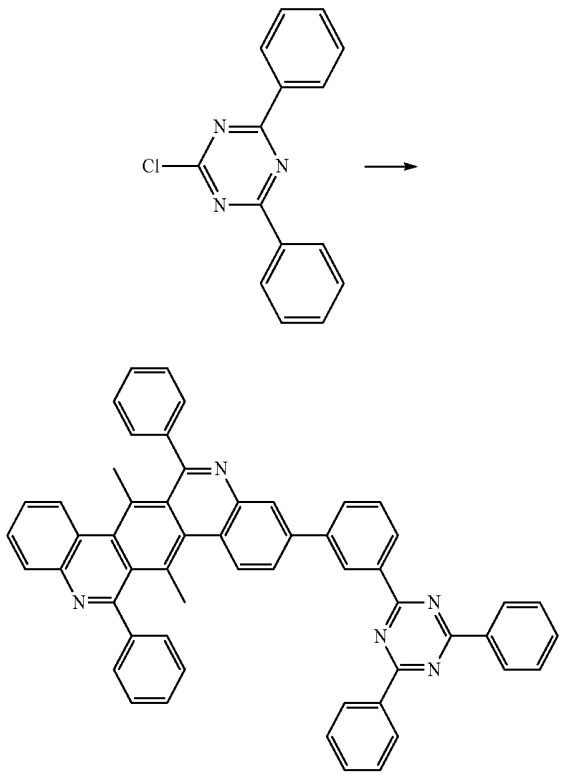


51

[0396] Synthesis of Intermediate 51-1

[0397] 5.86 g (10 mmol) of Intermediate 18-1, 4.25 g (15 mmol) of 1-bromo-5-iodobenzene, 0.58 g (0.5 mmol) of $Pd(PPh_3)_4$ (tetrakis(triphenylphosphine)palladium), and 4.14 g (30 mmol) of K_2CO_3 were dissolved in 60 mL of a mixed solvent of THF/H_2O (volume ratio of 2/1) and stirred at a temperature of 80° C. for 16 hours. The reaction solution was cooled to ambient temperature. Then, 40 mL of water was added to the reaction solution, and an extraction process was performed thereon three times using 50 mL of ethyl ether. An organic layer collected therefrom was dried using magnesium sulfate, and a solvent was evaporated therefrom. The residue obtained therefrom was separated and purified by silica gel column chromatography to obtain 4.62 g (yield: 75%) of Compound 51-1. The obtained compound was identified by LC-MS. $C_{40}H27BrN_2$: M^+ 614.1.

[0398] Synthesis of Intermediate 51-2

[0399] 6.16 g (10 mmol) of Intermediate 51-1 was dissolved in 30 mL of THF, and 4 mL of n-butyl lithium (2.5 M in hexane) was added thereto at a temperature of −78° C. After 1 hour, 2.04 mL (10 mmol) of 2-isopropoxy-4,4,5,5-tetramethyl-1,3,2-dioxaborolane was added thereto at the same temperature. The resultant mixture was stirred at ambient temperature for 5 hours. Then, water was added to the resultant mixture, and washing thereof was performed three times using 30 mL of diethyl ether. A layer of the diethyl ether used for the washing was dried using $MgSO_4$ and then dried under reduced pressure. A product obtained therefrom was separated and purified by silica gel column chromatography to obtain 4.64 g (yield: 70%) of Intermediate 51-2. The obtained compound was identified by LC-MS. $C_{46}H_{39}BN_2O_2$: M^+ 662.3.

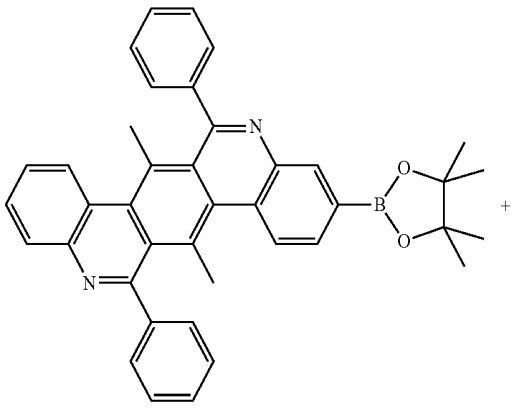
[0400] Synthesis of Compound 51

[0401] 6.63 g (10 mmol) of Intermediate 51-2, 2.68 g (10 mmol) of 2-chloro-4,6-diphenyl-1,3,5-triazine, 0.58 g (0.5 mmol) of $Pd(PPh_3)_4$ (tetrakis(triphenylphosphine)palladium), and 4.14 g (30 mmol) of K_2CO_3 were dissolved in 60 mL of a mixed solvent of THF/H_2O (volume ratio of 2/1) and stirred at a temperature of 80° C. for 16 hours. The reaction solution was cooled to ambient temperature. Then, 40 mL of water was added to the reaction solution, and an extraction process was performed thereon three times using 50 mL of ethyl ether. An organic layer collected therefrom was dried using magnesium sulfate, and a solvent was evaporated therefrom. A product obtained therefrom was separated and purified by silica gel column chromatography to obtain 4.79 g (yield: 65%) of Compound 51. The obtained compound was identified by MS/FAB and ^1H NMR. $C_{52}H_{37}N_2OP$: M^+ cal.: 736.26, found: 736.16.

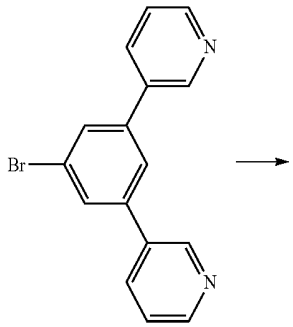
[0402] ^1H NMR (400 MHz, $CDCl_3$) δ (ppm) 8.93 (d, 1H), 8.79 (d, 4H), 8.73-8.70 (m, 2H), 8.58 (d, 1H), 8.20 (s, 1H), 8.06 (d, 1H), 7.99-7.85 (m, 7H), 7.67-7.59 (m, 12H), 7.42-7.38 (m, 2H), 2.99 (s, 3H), 2.97 (s, 3H).

Synthesis Example 8: Synthesis of Compound 56

[0403]



18-1



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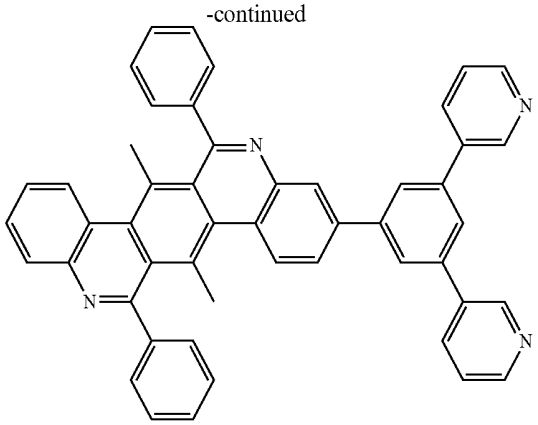


56

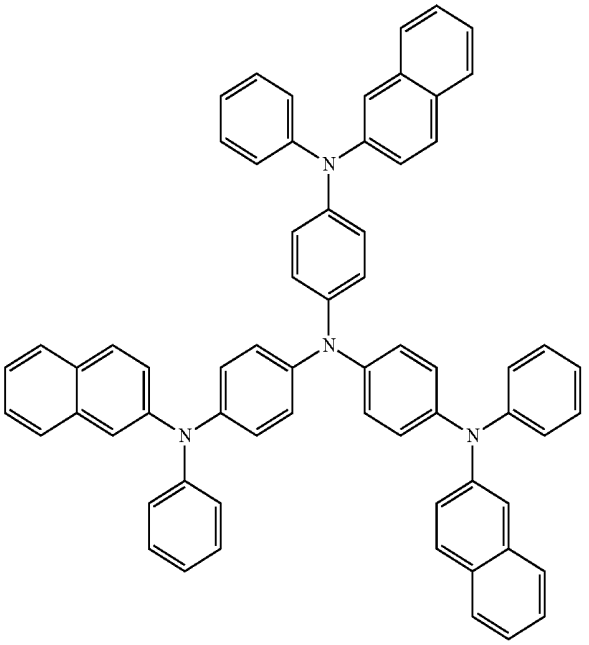
[0404] 5.86 g (10 mmol) of Intermediate 18-1, 3.11 g (10 mmol) of 3,3'-(5-bromo-1,3-phenylene)dipyridine, 0.58 g (0.5 mmol) of $Pd(PPh_3)_4$ (tetrakis(triphenylphosphine)palladium), and 4.14 g (30 mmol) of K_2CO_3 were dissolved in 60 mL of a mixed solvent of THF/H_2O (volume ratio of 2/1) and stirred at a temperature of 80° C. for 16 hours. The reaction solution was cooled to ambient temperature. Then, 40 mL of water was added to the reaction solution, and an extraction process was performed thereon three times using 50 mL of ethyl ether. An organic layer collected therefrom was dried using magnesium sulfate, and a solvent was evaporated therefrom. The residue obtained therefrom was separated and purified by silica gel column chromatography to obtain 4.49 g (yield: 65%) of Compound 51. The obtained compound was identified by MS/FAB and ^1H NMR. $C_{50}H_{34}N_4$: M^+ cal.: 690.28, found: 690.18.

[0405] ^1H NMR (400 MHz, $CDCl_3$) δ (ppm) 8.94-8.92 (m, 3H), 8.67 (d, 2H), 8.44 (d, 1H), 8.20 (s, 1H), 8.07-7.84 (m, 12H), 7.67-7.60 (m, 7H), 7.50-7.46 (m, 2H), 2.99 (s, 3H), 2.97 (s, 3H).

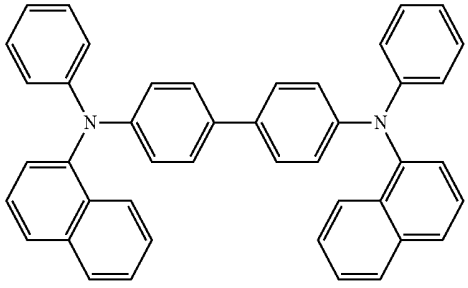
[0406] Synthesis methods of compounds other than Compounds synthesized according to Synthesis Examples 1 to 8 may be recognized by referring to the synthesis mechanisms and source materials described above.

Example 1

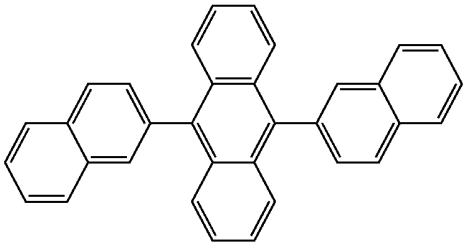
[0407] As an anode, a Corning 15 Ω/cm^2 (1,200 Å) ITO glass substrate was cut to a size of 50 mm×50 mm×0.7 mm, then sonicated with isopropyl alcohol and pure water each for 5 minutes, and then cleaned by irradiation with ultraviolet rays and exposure to ozone for 30 minutes, and the resultant glass substrate was provided to a vacuum deposition apparatus.



2-TNATA



NPB



ADN

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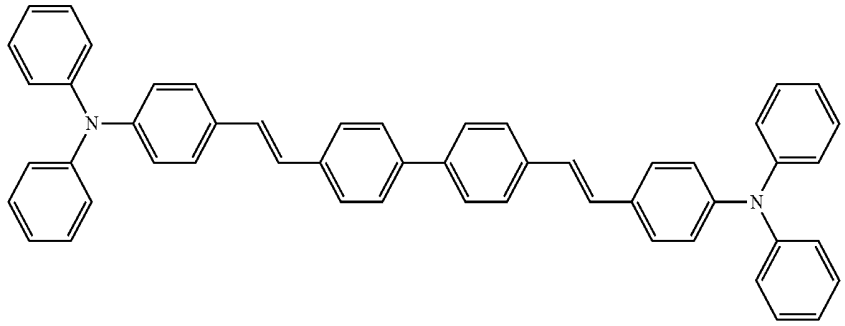


DPAVBi

[0408] 2-TNATA was vacuum-deposited on the ITO glass substrate to form a hole injection layer having a thickness of 600 Å, and 4,4'-bis[N-(1-naphthyl)-N-phenylamino]biphenyl (NPB) was vacuum-deposited on the hole injection layer to form a hole transport layer having a thickness of 300 Å. 9,10-di-naphthalene-2-yl-anthracene (ADN) a blue fluorescent host, and 4,4'-bis[2-(4-(N,N-diphenylamino)phenyl)vinyl]biphenyl (DPAVBi), a 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 300 Å.

[0409] Then, Compound 4 was deposited on the emission layer to form an electron transport layer having a thickness of 300 Å, LiF was deposited on the electron transport layer to form an electron injection layer having a thickness of 10 Å, and Al was vacuum-deposited on the electron transport layer to f Å orm a LiF/Al electrode (cathode electrode) having a thickness of 3,000 Å, thereby completing the manufacture of an organic light-emitting device.

[0410] The organic light-emitting device showed a driving voltage of 5.05 V, a light emission luminance of 3,020 cd/m^2, a light emission efficiency of 5.76 cd/A, and a half lifespan (hr @100 mA/cm^2) of 273 hours at a current density of 50 mA/cm^2.

Example 2

[0411] An organic light-emitting device of Example 2 was manufactured in the same manner as in Example 1, except that Compound 9 was used instead of Compound 4 in forming the electron transport layer.

Example 3

[0412] An organic light-emitting device of Example 3 was manufactured in the same manner as in Example 1, except that Compound 18 was used instead of Compound 4 in forming the electron transport layer.

Example 4

[0413] An organic light-emitting device of Example 4 was manufactured in the same manner as in Example 1, except that Compound 43 was used instead of Compound 4 in forming the electron transport layer.

Example 5

[0414] An organic light-emitting device of Example 5 was manufactured in the same manner as in Example 1, except that Compound 45 was used instead of Compound 4 in forming the electron transport layer.

Example 6

[0415] An organic light-emitting device of Example 6 was manufactured in the same manner as in Example 1, except that Compound 46 was used instead of Compound 4 in forming the electron transport layer.

Example 7

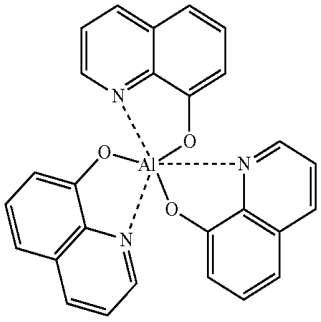
[0416] An organic light-emitting device of Example 7 was manufactured in the same manner as in Example 1, except that Compound 51 was used instead of Compound 4 in forming the electron transport layer.

Example 8

[0417] An organic light-emitting device of Example 8 was manufactured in the same manner as in Example 1, except that Compound 56 was used instead of Compound 4 in forming the electron transport layer.

Comparative Example 1

[0418] An organic light-emitting device of Comparative Example 1 was manufactured in the same manner as in Example 1, except that Alq_3 was used instead of Compound 4 in forming the electron transport layer.



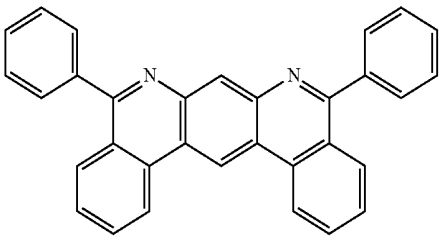
Alq_3

[0419] The organic light-emitting device of Comparative Example 1 showed a driving voltage of 7.35 V, a light emission luminance of 2,065 cd/m^2, a light emission efficiency of 4.13 cd/A, and a half lifespan (hr @100 mA/cm^2) of 145 hours at a current density of 50 mA/cm^2.

Comparative Example 2

[0420] An organic light-emitting device of Comparative Example 2 was manufactured in the same manner as in Example 1, except that Compound A was used instead of Compound 4 in forming the electron transport layer.

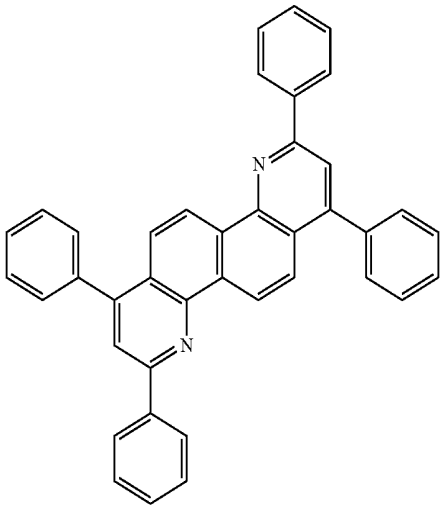
<Compound A>



Comparative Example 3

[0421] An organic light-emitting device of Comparative Example 3 was manufactured in the same manner as in Example 1, except that Compound B was used instead of Compound 4 in forming the electron transport layer.

<Compound B>



[0422] The driving voltage, luminance, efficiency (cd/A), and half lifespan of the organic light-emitting devices manufactured according to Examples 1 to 8 and Comparative Examples 1 to 3 were measured at a current density of 50 mA/cm^2. Results thereof are shown in Table 1.

TABLE 1

	Material	Driving 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 4	5.80	50	3,050	6.10	Blue	322 hr
Example 2	Compound 9	5.72	50	3,075	6.15	Blue	365 hr
Example 3	Compound 18	5.69	50	3,190	6.38	Blue	335 hr
Example 4	Compound 43	5.65	50	3,175	6.35	Blue	350 hr
Example 5	Compound 45	5.52	50	3,265	6.53	Blue	290 hr
Example 6	Compound 46	5.68	50	3,225	6.45	Blue	300 hr
Example 7	Compound 51	5.56	50	3,310	6.62	Blue	280 hr
Example 8	Compound 56	5.65	50	3,330	6.66	Blue	340 hr
Comparative Example	Alq_3	7.35	50	2,065	4.13	Blue	145 hr
Comparative Example 2	Compound A	6.38	50	2,790	5.58	Blue	250 hr
Comparative Example 3	Compound B	6.53	50	2,825	5.65	Blue	230 hr

[0423] Referring to Table 1, it may be seen that when the Compounds of Examples 1 to 8 were used as electron transport materials, there was a reduction in driving voltage by 1 V or more and excellent I-V-L characteristics having remarkably improved efficiency were shown, as compared to when Alq_3 was used. For example, excellent lifespan improvement effects were shown.

[0424] Also, as compared with Comparative Examples 2 and 3 that respectively used Compounds A and B as electron transport materials, driving voltage was reduced and both luminance and lifespan were improved.

[0425] For example, when Compounds according to one or more embodiments are used as the electron transport material of the organic light-emitting device, the organic light-emitting device exhibited excellent effects in terms of driving voltage, luminance, efficiency, and lifespan.

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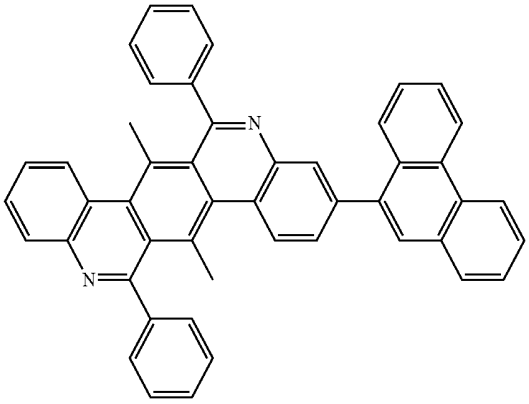
4



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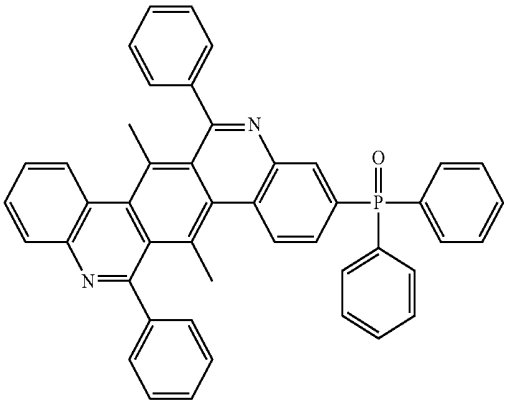

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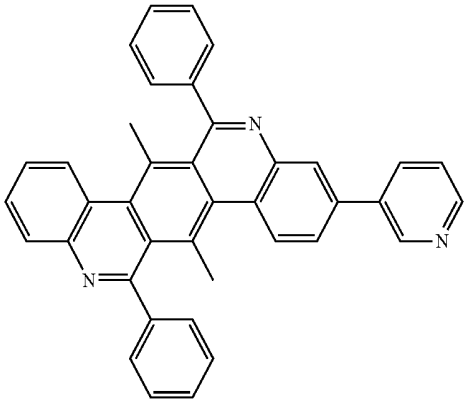

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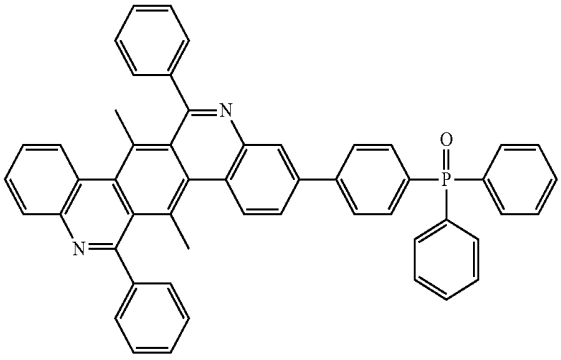

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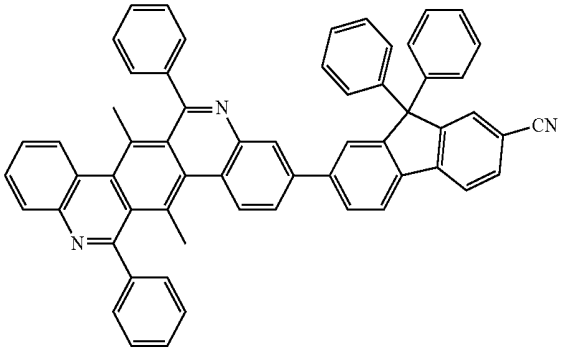

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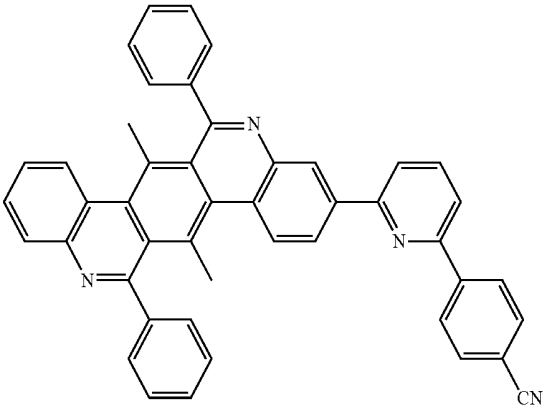

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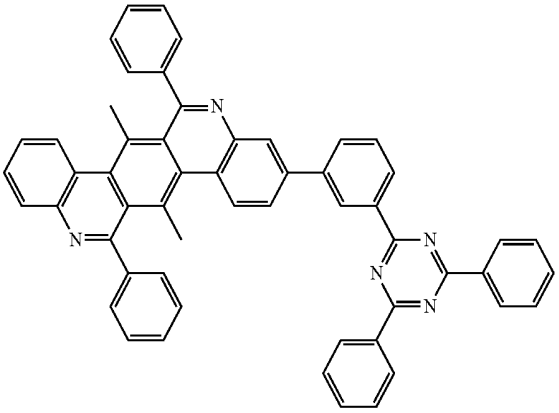

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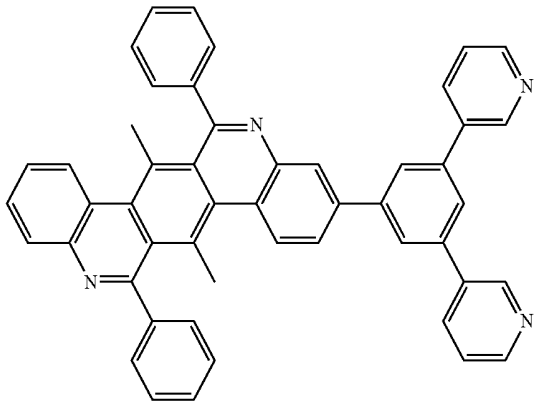
56



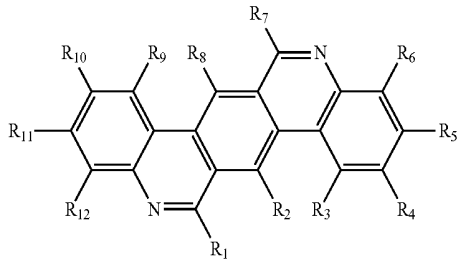
[0426] According to one or more embodiments, an organic light-emitting device may have a low driving voltage, high efficiency, and a long lifespan.

[0427] Example embodiments have been disclosed herein, and although specific terms are employed, they are used and are to be interpreted in a generic and descriptive sense only and not for purpose of limitation. In some instances, as would be apparent to one of ordinary skill in the art as of the filing of the present application, features, characteristics, and/or elements described in connection with a particular embodiment may be used singly or in combination with features, characteristics, and/or elements described in connection with other embodiments unless otherwise specifically indicated. Accordingly, it will be understood by those of skill in the art that various changes in form and details may be made without departing from the spirit and scope of the present invention as set forth in the following claims.

What is claimed is:

1. A condensed cyclic compound represented by Formula 1:

<Formula 1>



wherein, in Formula 1, R_1 to R_{12} are each independently a group represented by Formula 2, 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, or a substituted or unsubstituted C_1-C_{60} alkoxy group, provided that at least one of R_1 to R_{12} is not hydrogen,

<Formula 2>

$$*\text{-}(L_1)_{a1}\text{-}(Ar_1)_{b1},$$

wherein, in Formula 2,

L_1 is a substituted or unsubstituted C_3-C_{60} carbocyclic group, a substituted or unsubstituted C_1-C_{60} heterocyclic group, *—$Si(Q_1)(Q_2)$-*', *—$N(Q_1)$-*', *—$B(Q_1)$-*', *—$C(=O)$—*', *—$S(=O)_2$—*', or *—$P(=O)(Q_1)$-*',

a1 is an integer of 0 to 4, wherein, when a1 is zero, *-$(L_1)_{a1}$-*' is a single bond, and when a1 is 2, 3, or 4, the 2, 3, or 4 L_1(s) are identical to or different from each other,

Ar_1 is a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —$Si(Q_1)(Q_2)(Q_3)$, —$N(Q_1)(Q_2)$, —$B(Q_1)(Q_2)$, —$C(=O)(Q_1)$, —$S(=O)_2(Q_1)$, or —$P(=O)(Q_1)(Q_2)$,

b1 is an integer of 1 to 4, wherein, when b1 is 2, 3, or 4, the 2, 3, or 4 Ar_1(s) are identical to or different from each other,

at least one substituent of the substituted C_3-C_{60} carbocyclic group, the substituted C_1-C_{60} heterocyclic 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, and the substituted monovalent non-aromatic condensed heteropolycyclic group is selected from:

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

a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, 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, —$Si(Q_1)(Q_{12})(Q_{13})$, —$N(Q_{11})(Q_{12})$, —$B(Q_1)(Q_{12})$, —$C(=O)(Q_{11})$, —$S(=O)_2(Q_{11})$, and —$P(=O)(Q_{11})(Q_{12})$;

a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} 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, a biphenyl group, and a terphenyl 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, 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_{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, a biphenyl group, a terphenyl group, $—Si(Q_{21})(Q_{22})(Q_{23})$, $—N(Q_{21})(Q_{22})$, $—B(Q_{21})(Q_{22})$, $—C(=O)(Q_{21})$, $—S(=O)_2(Q_{21})$, and $—P(=O)(Q_{21})(Q_{22})$; and

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

Q_1 to Q_3, 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_6-C_{60} aryl group substituted with a C_1-C_{60} alkyl 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, and a terphenyl group, and

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

2. The condensed cyclic compound as claimed in claim **1**, wherein:

a1 is an integer of 1 to 4,

L_1 is:

a benzene group, a pentalene group, an indene group, a naphthalene group, an azulene group, a heptalene group, an indacene group, an acenaphthalene group, a fluorene group, a spiro-bifluorene group, a spiro-benzofluorene-fluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pyrrole group, a thiophene group, a furan group, a silole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a triazine group, a benzofuran group, a benzothiophene group, a benzosilole group, a dibenzofuran group, a dibenzothiophene group, a dibenzosilole group, a carbazole group, a quinoline group, an isoquinoline group, a benzocarbazole group, a dibenzocarbazole group, a benzimidazole group, an imidazopyridine group, or an imidazopyrimidine group;

a benzene group, a pentalene group, an indene group, a naphthalene group, an azulene group, a heptalene group, an indacene group, an acenaphthalene group, a fluorene group, a spiro-bifluorene group, a spiro-benzofluorene-fluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pyrrole group, a thiophene group, a furan group, a silole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a triazine group, a benzofuran group, a benzothiophene group, a benzosilole group, a dibenzofuran group, a dibenzothiophene group, a dibenzosilole group, a carbazole group, a quinoline group, an isoquinoline group, a benzocarbazole group, a dibenzocarbazole group, a benzimidazole group, an imidazopyridine group, or an imidazopyrimidine group, each substituted with deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a carbazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, $—Si(Q_{31})(Q_{32})(Q_{33})$, $—N(Q_{31})(Q_{32})$, or $—B(Q_{31})(Q_{32})$; or

$*—S(=O)_2—*'$ and $*—P(=O)(Q_1)-*'$,

Q_1 and Q_{31} to Q_{33} are each independently 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, or a pyridinyl group, and

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

3. The condensed cyclic compound as claimed in claim **1**, wherein:

a1 is an integer of 1 to 4,

L_1 is:

a benzene group, a naphthalene group, an anthracene group, a fluorene group, a spiro-bifluorene group, a

pyridine group, a pyrimidine group, a triazine group, a carbazole group, a quinoline group, or an isoquinoline group;

a benzene group, a naphthalene group, an anthracene group, a fluorene group, a spiro-bifluorene group, a pyridine group, a pyrimidine group, a triazine group, a carbazole group, a quinoline group, or an isoquinoline group, each substituted with a cyano group, a C_1-C_{20} alkyl group, a phenyl group, a biphenyl group, a pyridinyl group, or a fluorenyl group; or

—S(═O)$_2$—' or *—P(═O)(Q_1)-*',

Q_1 is 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, or a pyridinyl group, and

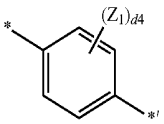
and *' each indicate a binding site to a neighboring atom.

4. The condensed cyclic compound as claimed in claim **1**, wherein:

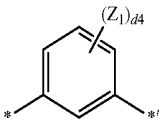
a1 is an integer of 1 to 4, and

L_1 is a group represented by one of Formulae 3-1 to 3-31, 3-31', and 3-32 to 3-35:

Formula 3-1



Formula 3-2



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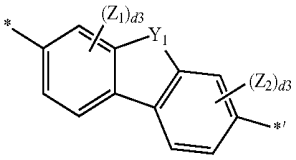

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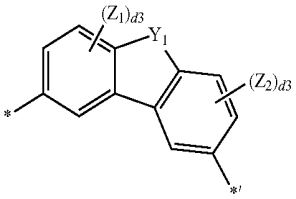
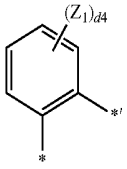
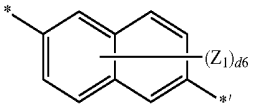


Formula 3-5



Formula 3-6



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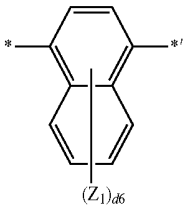

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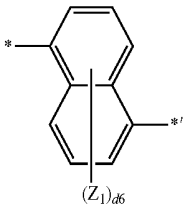

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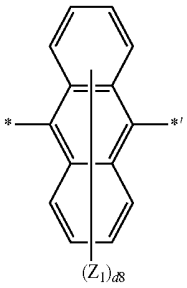

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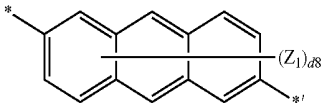

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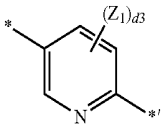

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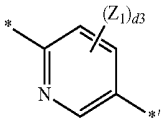
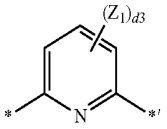
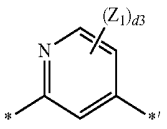


Formula 3-13



Formula 3-14



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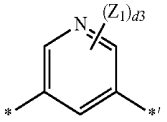

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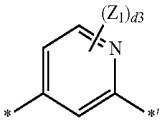
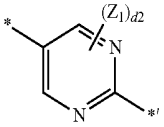
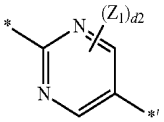


Formula 3-17



3Formula 3-18



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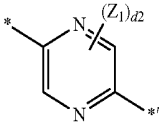
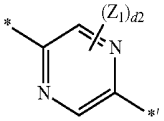
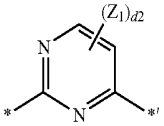


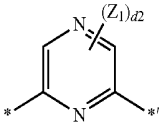
Formula 3-20



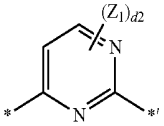
Formula 3-21



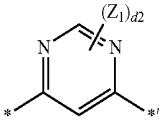
Formula 3-22



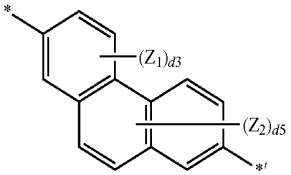
Formula 3-23



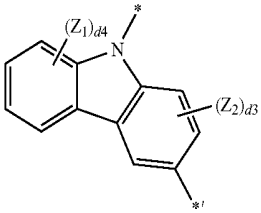
Formula 3-24



Formula 3-25



Formula 3-26



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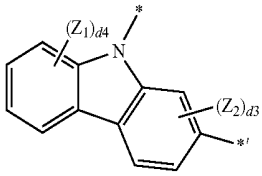
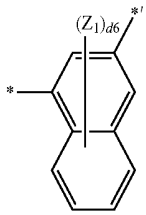
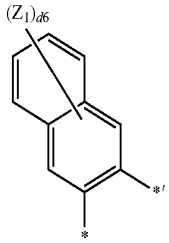
Formula 3-27



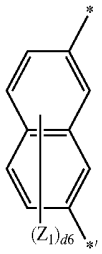
Formula 3-28



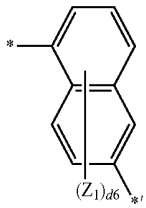
Formula 3-29



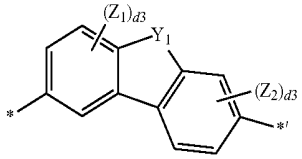
Formula 3-30



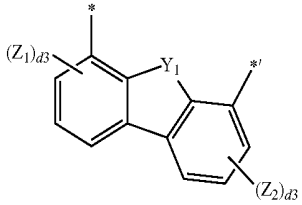
Formula 3-31



Formula 3-32



Formula 3-31'



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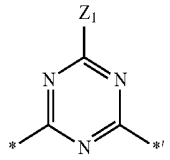
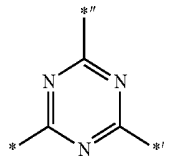
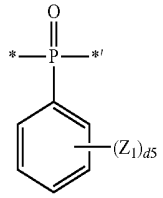
Formula 3-32′



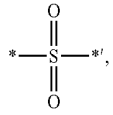
Formula 3-33



Formula 3-34



Formula 3-35



wherein, in Formulae 3-1 to 3-31, 3-31', 3-32', 3-32 to 3-35,

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

Z_1 to Z_7 are each independently deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a 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 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, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, or —$Si(Q_3)(Q_{32})(Q_{33})$,

Q_{31} to Q_{33} are each independently 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, or a pyridinyl group,

d2 is an integer of 0 to 2,

d3 is an integer of 0 to 3,

d4 is an integer of 0 to 4,

d5 is an integer of 0 to 5,

d6 is an integer of 0 to 6,

d8 is an integer of 0 to 8, and

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

5. The condensed cyclic compound as claimed in claim **1**, wherein:

Ar_1 is:

a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a thiophenyl group, a furanyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzonaphthofuranyl group, a dinaphthofuranyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a benzonaphthosilolyl group, a dinaphthosilolyl group, a benzimidazolyl group, or an imidazopyridinyl group;

a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a thiophenyl group, a furanyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzonaphthofuranyl group, a dinaphthofuranyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a benzonaphthosilolyl group, a dinaphthosilolyl group, a benzimidazolyl group, or an imidazopyridinyl group, each substituted with 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, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl

group, an ovalenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a thiophenyl group, a furanyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, —$N(Q_{31})(Q_{32})$, or —$Si(Q_{31})(Q_{32})(Q_{33})$; or

—$S(=O)(Q_1)(Q_2)$, —$S(=O)_2(Q_1)$, —$P(=O)(Q_1)(Q_2)$, —$P(=O)_2(Q_1)$, —$P(=S)(Q_1)(Q_2)$, or —$P(=S)_2(Q_1)$; and

Q_1, Q_2, and Q_{31} to Q_{33} are each independently 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, or a pyridinyl group.

6. The condensed cyclic compound as claimed in claim **5**, wherein:

Ar_1 is:

a phenyl group, a biphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a phenanthrenyl group, an anthracenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, or a carbazolyl group;

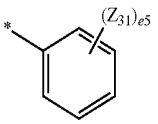
a phenyl group, a biphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a phenanthrenyl group, an anthracenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, or a carbazolyl group, each substituted with 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 naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyridinyl group, a pyrimidinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, —$N(Q_{31})(Q_{32})$, or —$Si(Q_{31})(Q_{32})(Q_{33})$; or

—$S(=O)(Q_1)(Q_2)$, —$S(=O)_2(Q_1)$, —$P(=O)(Q_1)(Q_2)$, —$P(=O)_2(Q_1)$, —$P(=S)(Q_1)(Q_2)$, or —$P(=S)_2(Q_1)$; and

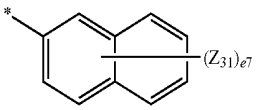
Q_1, Q_2, and Q_{31} to Q_{33} are each independently a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, or a pyridinyl group.

7. The condensed cyclic compound as claimed in claim **1**, wherein A_r is a group represented by one of Formulae 5-1 to 5-49, —$S(=O)(Q_1)(Q_2)$, —$S(=O)_2(Q_1)$, —$P(=O)(Q_1)(Q_2)$, —$P(=O)_2(Q_1)$, —$P(=S)(Q_1)(Q_2)$, or —$P(=S)_2(Q_1)$:

Formula 5-1



Formula 5-2



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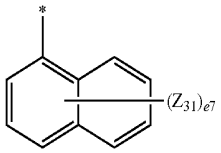
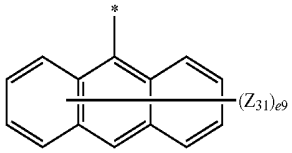
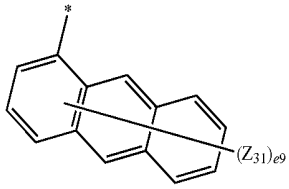
Formula 5-3



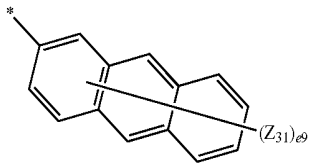
Formula 5-4



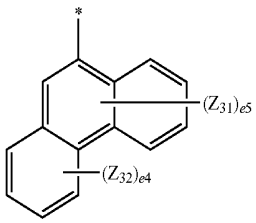
Formula 5-5



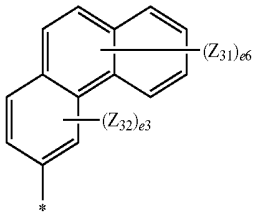
Formula 5-6



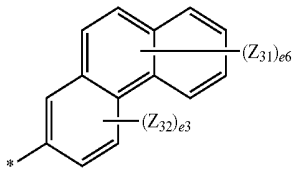
Formula 5-7



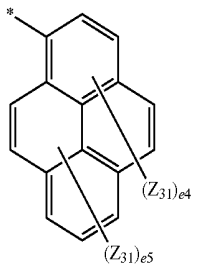
Formula 5-8



Formula 5-9



Formula 5-10



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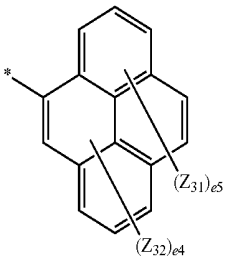
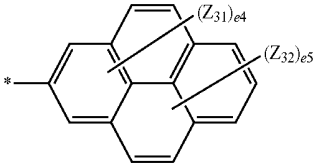
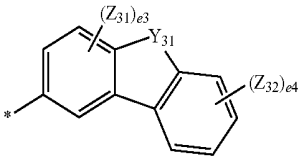
Formula 5-11



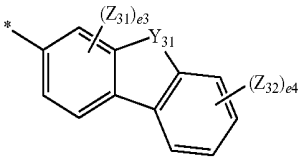
Formula 5-12



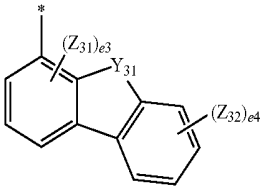
Formula 5-13



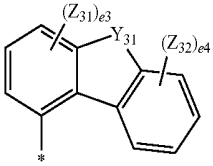
Formula 5-14



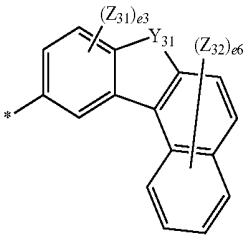
Formula 5-15



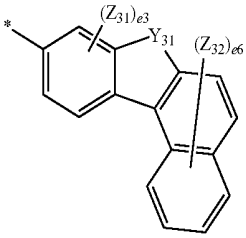
Formula 5-16



Formula 5-17



Formula 5-18



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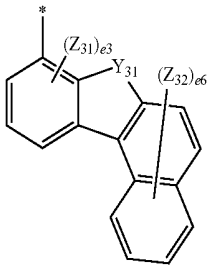
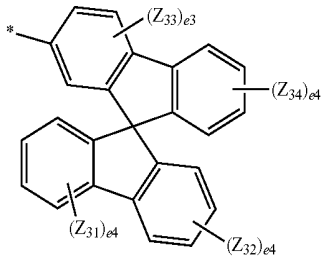
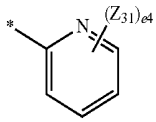
Formula 5-19



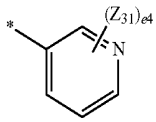
Formula 5-20



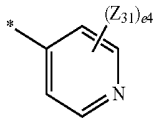
Formula 5-21



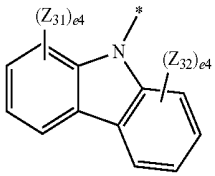
Formula 5-22



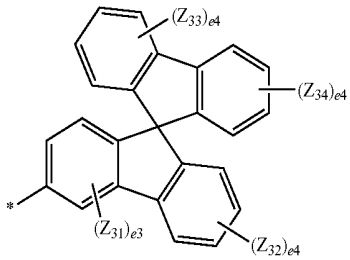
Formula 5-23



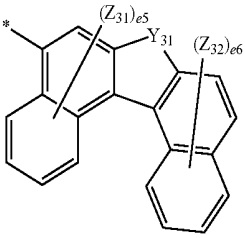
Formula 5-24



Formula 5-25



Formula 5-26



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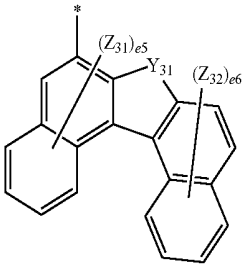
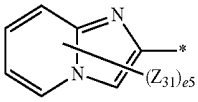
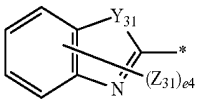
Formula 5-27



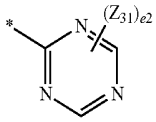
Formula 5-28



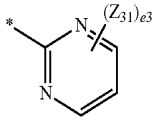
Formula 5-29



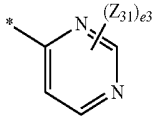
Formula 5-30



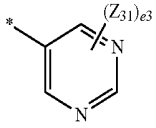
Formula 5-31



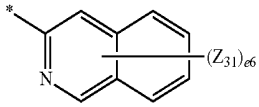
Formula 5-32



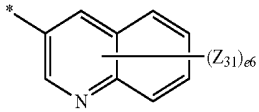
Formula 5-33



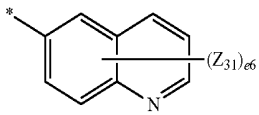
Formula 5-34



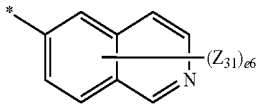
Formula 5-35



Formula 5-36



Formula 5-37



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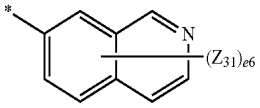
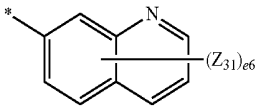
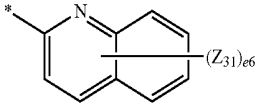
Formula 5-38



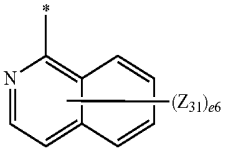
Formula 5-39



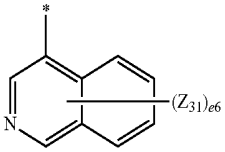
Formula 5-40



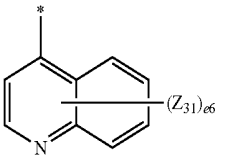
Formula 5-41



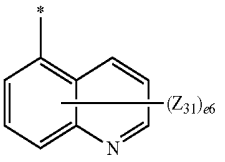
Formula 5-42



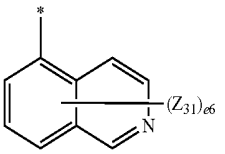
Formula 5-43



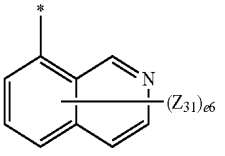
Formula 5-44



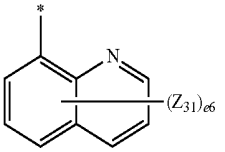
Formula 5-45



Formula 5-46



Formula 5-47



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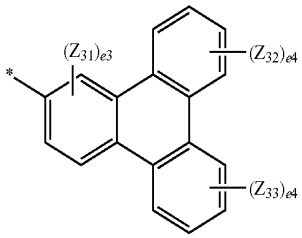
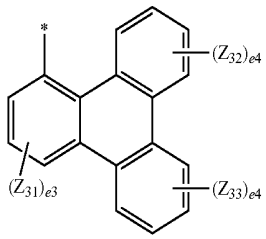
Formula 5-48



Formula 5-49



wherein, in Formulae 5-1 to 5-49,

Y_{31} is O, S, $C(Z_{33})(Z_{34})$, $N(Z_{35})$, or $Si(Z_{36})(Z_{37})$,

Z_{31} to Z_{37} are each independently deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl group, a pyridinyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a carbazolyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, or $—Si(Q_{31})(Q_{32})(Q_{33})$,

Q_1, Q_2, and Q_{31} to Q_{33} are each independently 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, or a pyridinyl group,

e2 is an integer of 0 to 2,

e3 is an integer of 0 to 3,

e4 is an integer of 0 to 4,

e5 is an integer of 0 to 5,

e6 is an integer of 0 to 6,

e7 is an integer of 0 to 7,

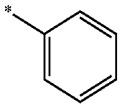
e9 is an integer of 0 to 9, and

indicates a binding site to a neighboring atom.

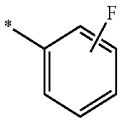
8. The condensed cyclic compound as claimed in claim **7**, wherein A_r is a group represented by one of Formulae 5-1 to 5-4, 5-7, 5-13, 5-14, 5-20 to 5-23, 5-30, 5-31, 5-34, 5-41, and 5-48, $—S(=O)_2(Q_1)$, or $—P(=O)(Q_1)(Q_2)$, in which Q_1 and Q_2 are each independently a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, or a pyridinyl group.

9. The condensed cyclic compound as claimed in claim **1**, wherein Ar_1 is a group represented by one of Formulae 6-1 to 6-110, a group represented by one of Formulae 10-1 to 10-11, $—S(=O)_2(Q_1)$, or $—P(=O)(Q_1)(Q_2)$, in which Q_1 and Q_2 are each independently 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, or a pyridinyl group:

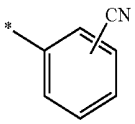
Formula 6-1



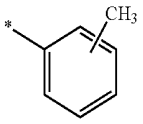
Formula 6-2



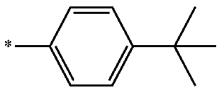
Formula 6-3



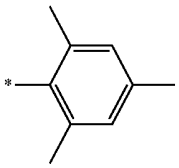
Formula 6-4



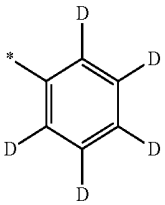
Formula 6-5



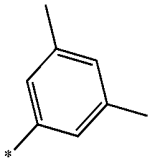
Formula 6-6



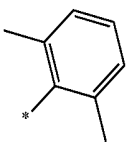
Formula 6-7



Formula 6-8



Formula 6-9



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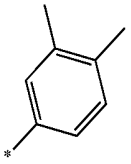
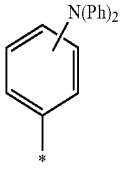
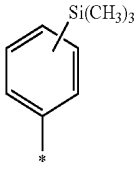
Formula 6-10



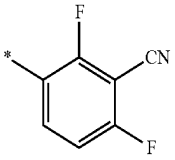
Formula 6-11



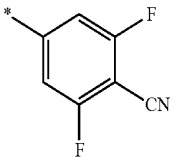
Formula 6-12



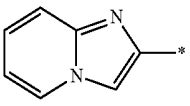
Formula 6-13



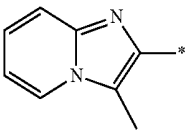
Formula 6-14



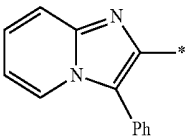
Formula 6-15



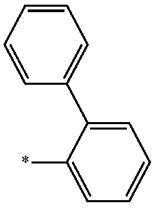
Formula 6-16



Formula 6-17



Formula 6-18



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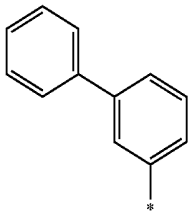
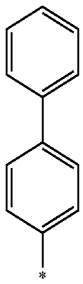
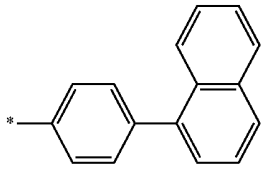
Formula 6-19



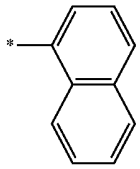
Formula 6-20



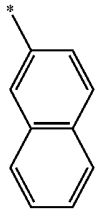
Formula 6-21



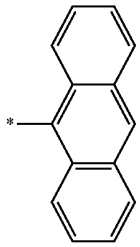
Formula 6-22



Formula 6-23



Formula 6-24



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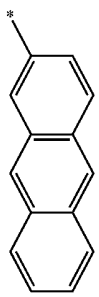

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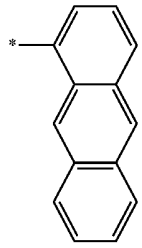

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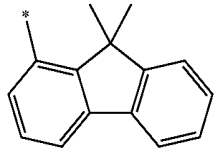

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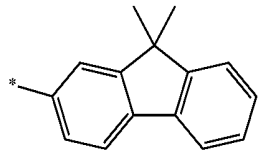

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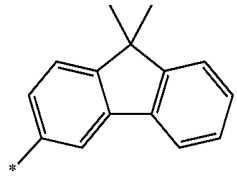

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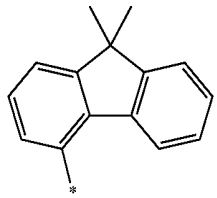

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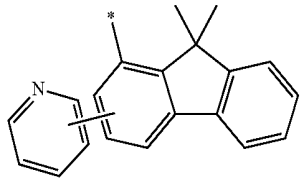

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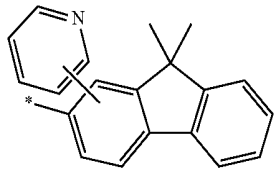

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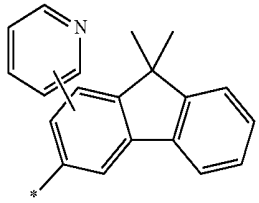

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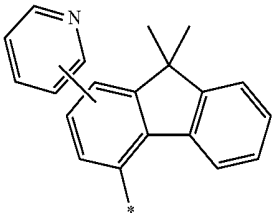

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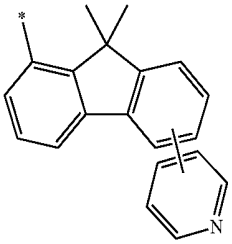

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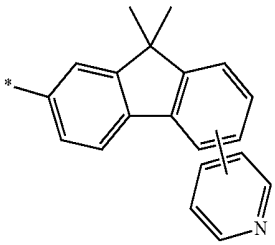

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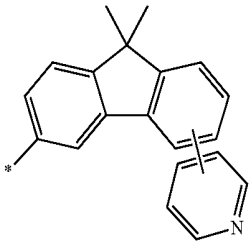

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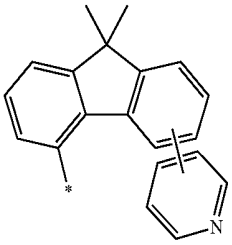

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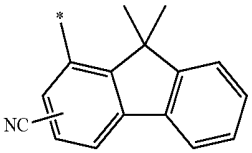

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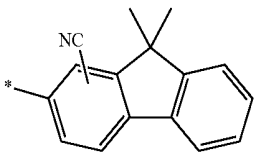

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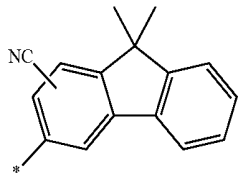

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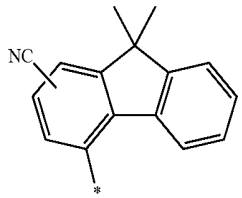

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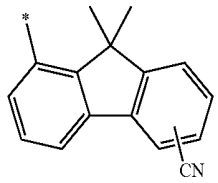

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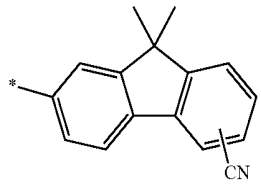

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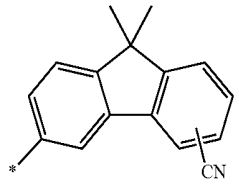

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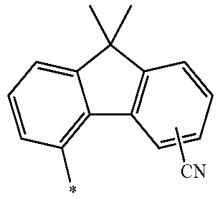

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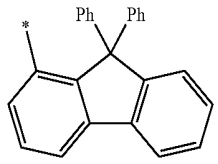

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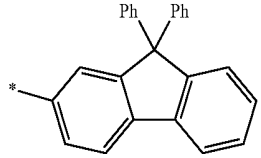

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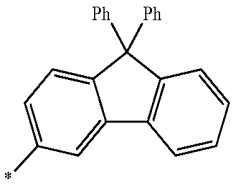

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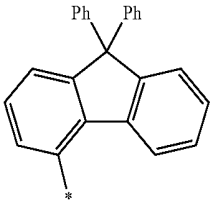

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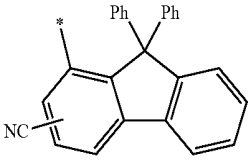

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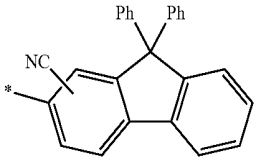

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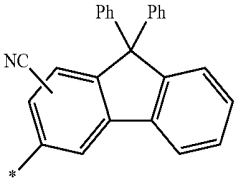

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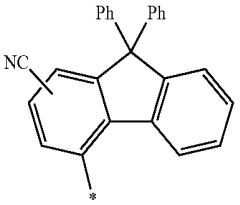

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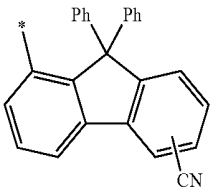

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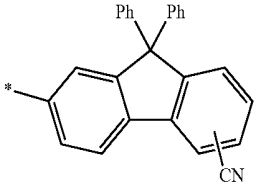

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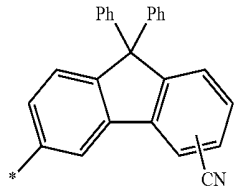

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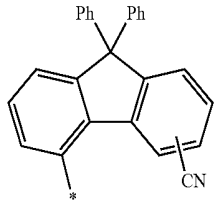

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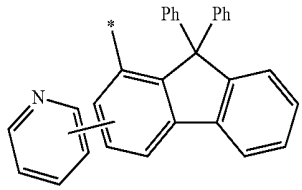

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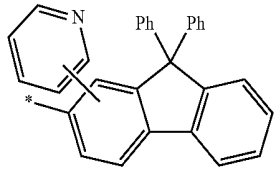

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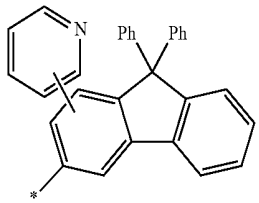

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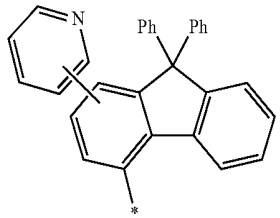

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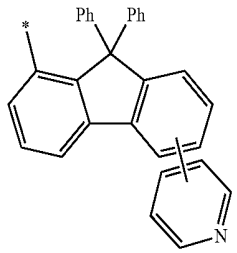

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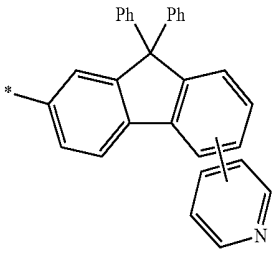

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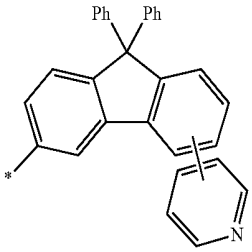

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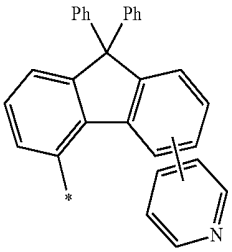

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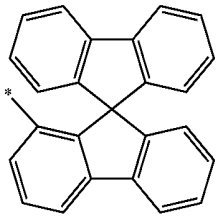

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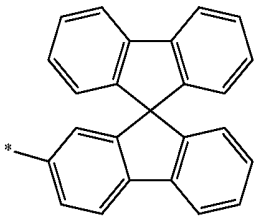

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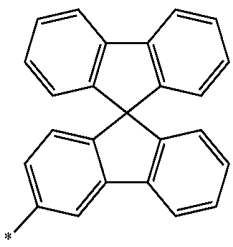

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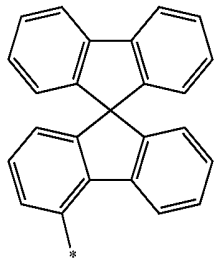

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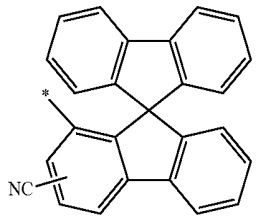

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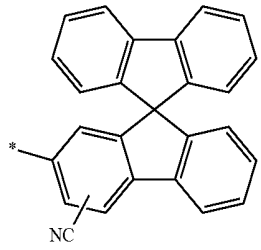

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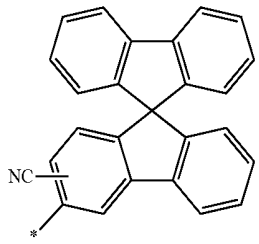

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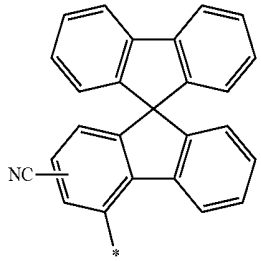

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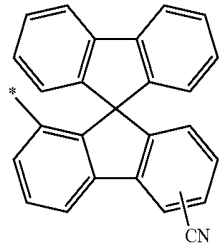

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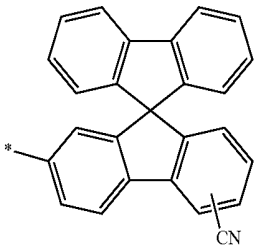

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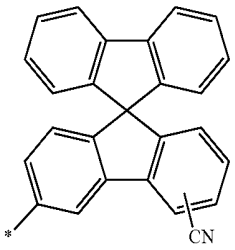

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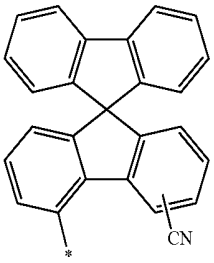

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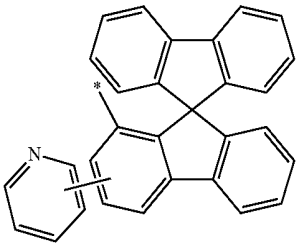

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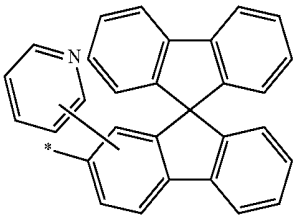
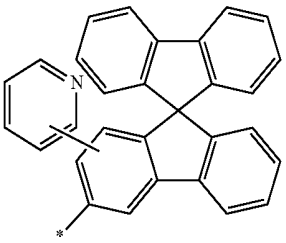


Formula 6-81



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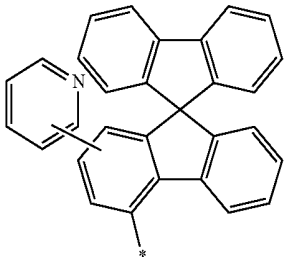

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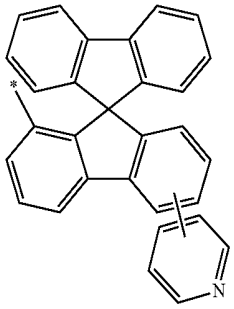

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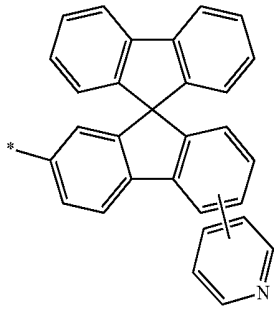

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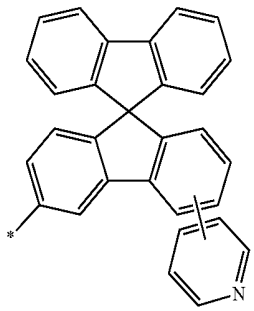

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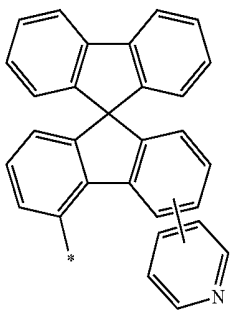

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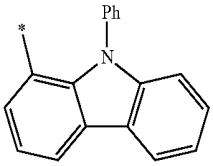

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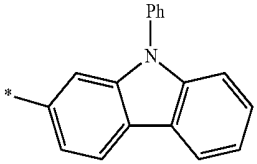

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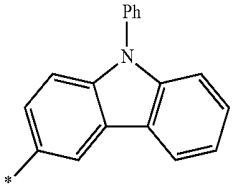

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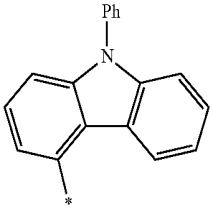

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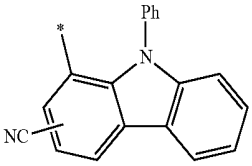

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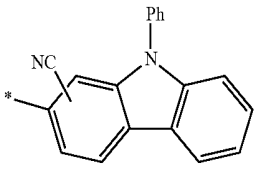

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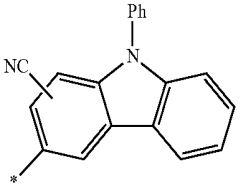

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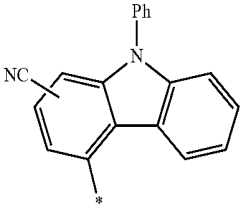

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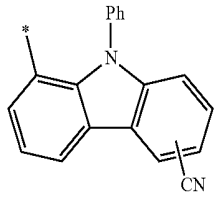

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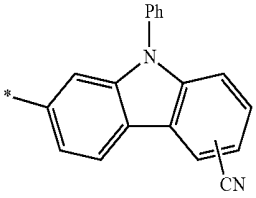

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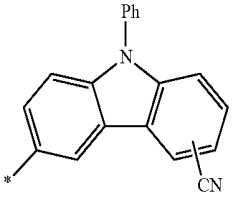

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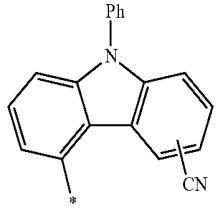

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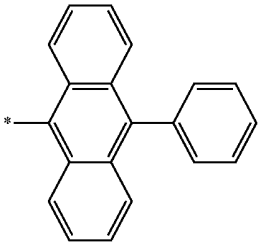

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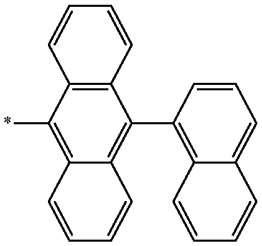

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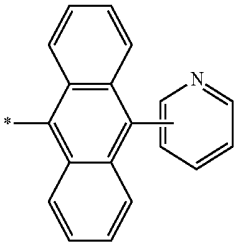

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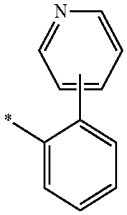

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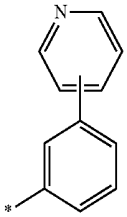

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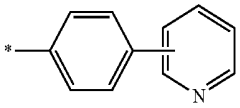

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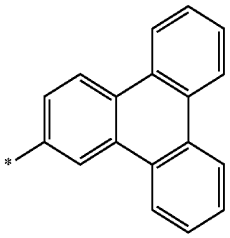

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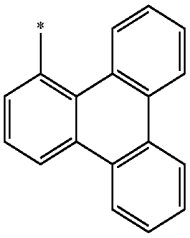

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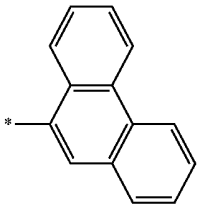

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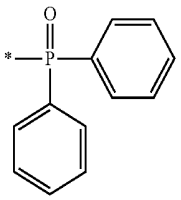

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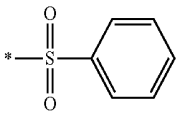

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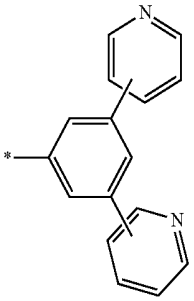

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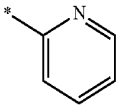

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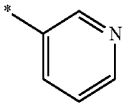

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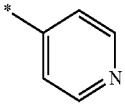

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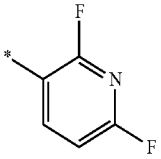

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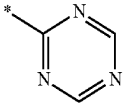

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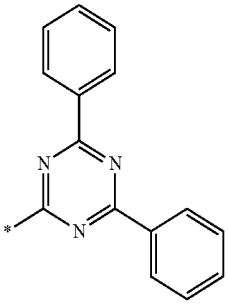

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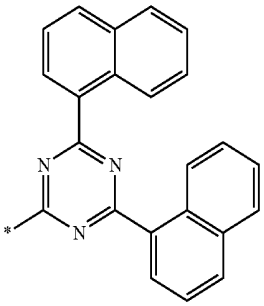

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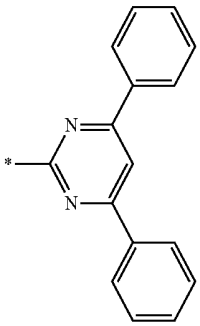

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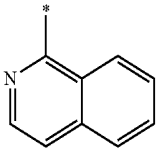

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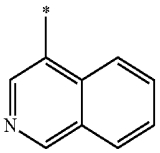
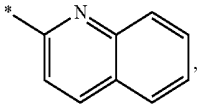


Formula 10-11



wherein, in Formulae 6-1 to 6-110 and 10-1 to 10-11, Ph indicates a phenyl group and * indicates a binding site to a neighboring atom.

10. The condensed cyclic compound as claimed in claim **1**, wherein at least one of R_1 to R_{12} is a group represented by Formula 2.

11. The condensed cyclic compound as claimed in claim **1**, wherein at least one of R_1, R_5, R_7, and R_{11} is a group represented by Formula 2.

12. The condensed cyclic compound as claimed in claim **1**, wherein at least one of R_2 and R_8 is a substituted or unsubstituted C_1-C_{60} alkyl group.

13. The condensed cyclic compound as claimed in claim **1**, wherein R_3, R_4, R_6, R_9, R_{10}, and R_{12} are each hydrogen.

14. The condensed cyclic compound as claimed in claim **1**, wherein:

i) R_1, R_5, and R_7 are each a group represented by Formula 2, R_2 and R_8 are each a substituted or unsubstituted C_1-C_{60} alkyl group, and R_3, R_4, R_6, R_9, R_{10}, R_{11}, and R_{12} are each hydrogen;

ii) R_1, R_5, R_7, and R_{11} are each a group represented by Formula 2, R_2 and R_8 are each a substituted or unsubstituted C_1-C_{60} alkyl group, and R_3, R_4, R_6, R_9, R_{10}, and R_{12} are each hydrogen; or

iii) R_1 and R_7 are each a group represented by Formula 2, R_2 and R_8 are each a substituted or unsubstituted C_1-C_{60} alkyl group, and R_3, R_4, R_5, R_6, R_9, R_{10}, R_{11}, and R_{12} are each hydrogen.

15. The condensed cyclic compound as claimed in claim **1**, wherein the condensed cyclic compound is one of Compounds 1 to 138:

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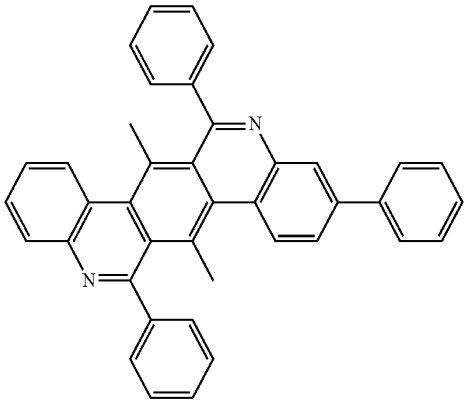
1



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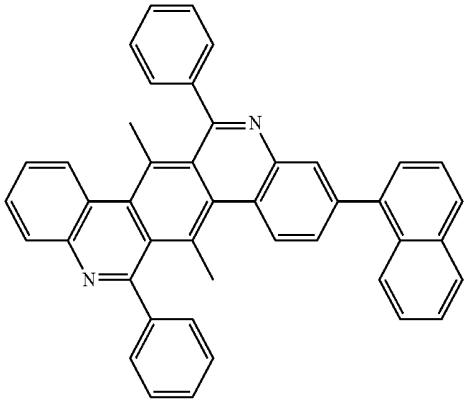

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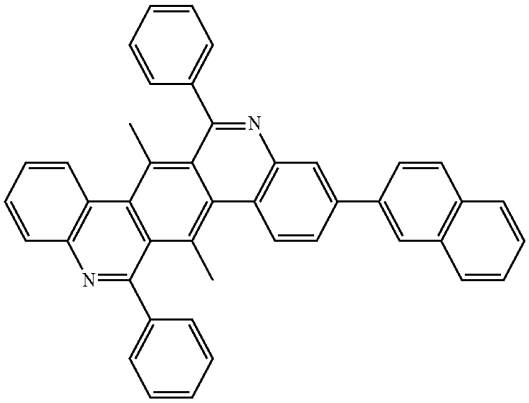

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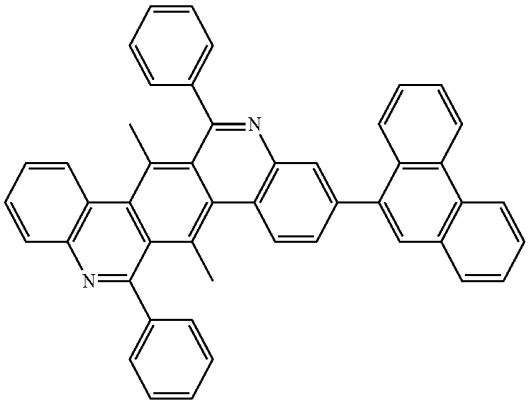

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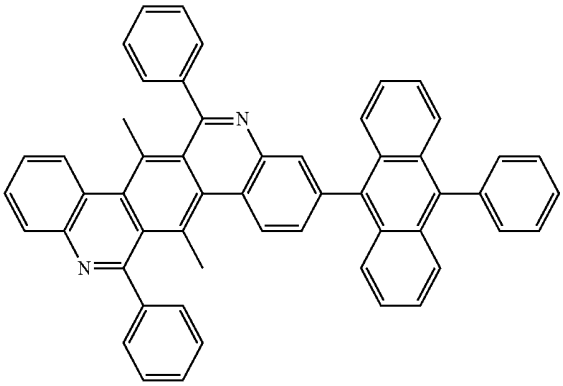

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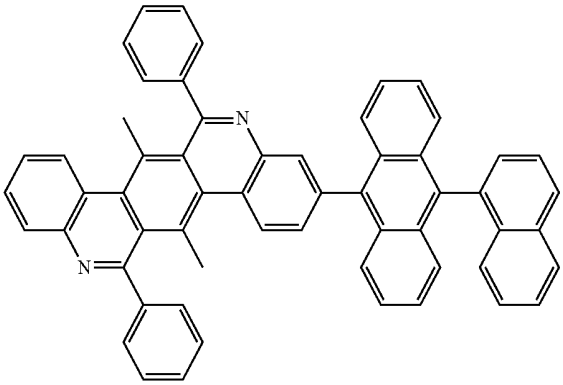

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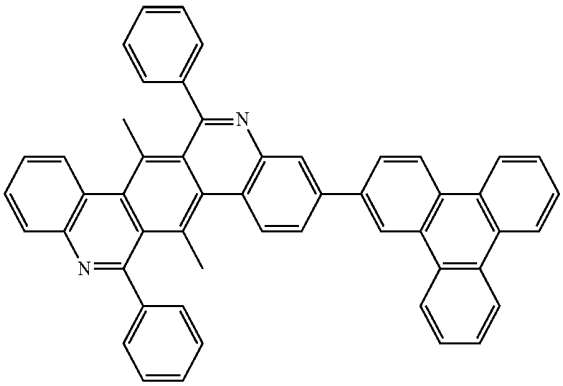

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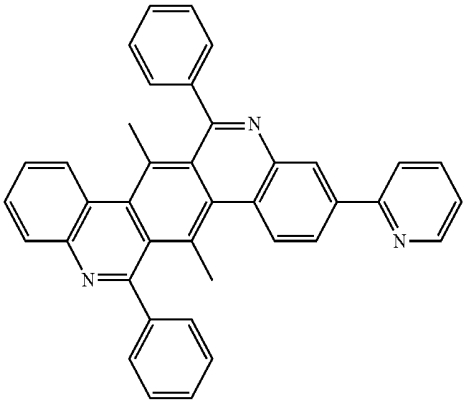

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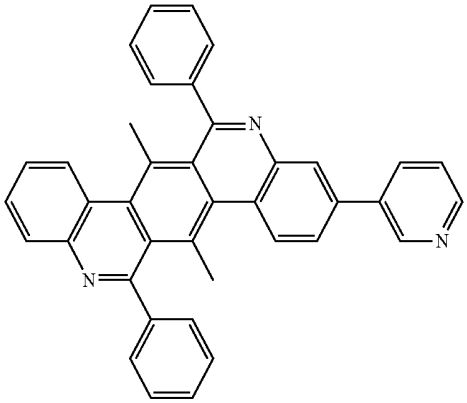

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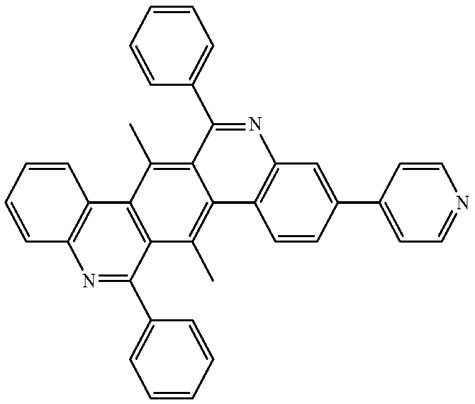

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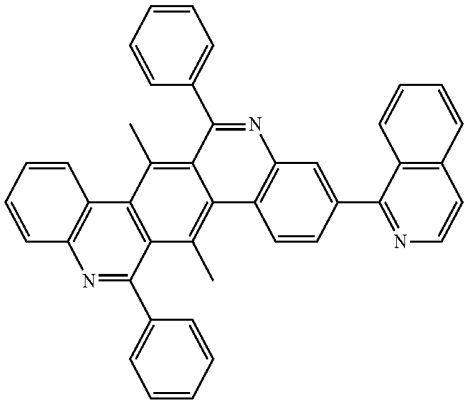

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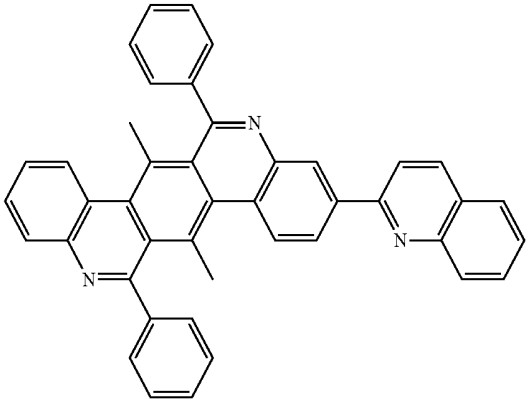

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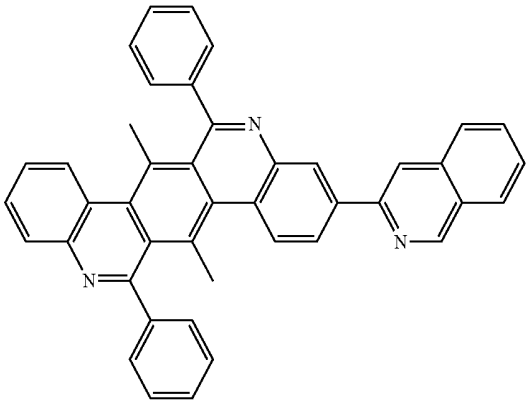

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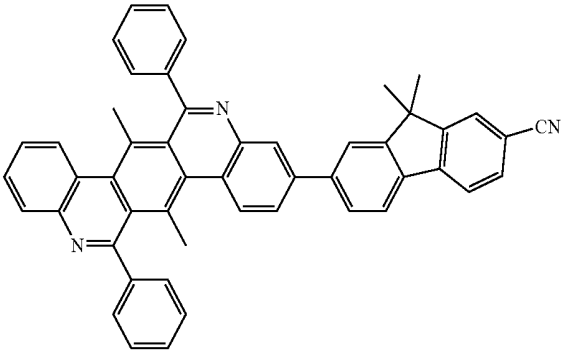

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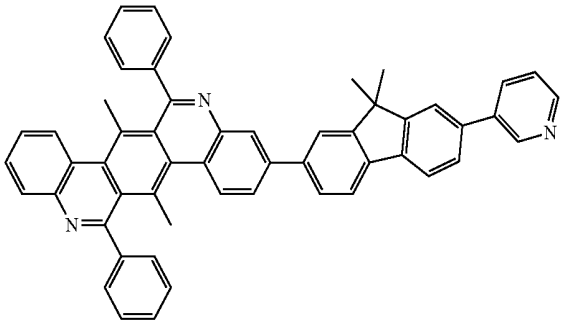

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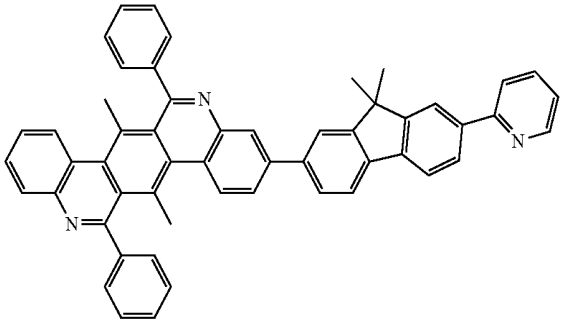

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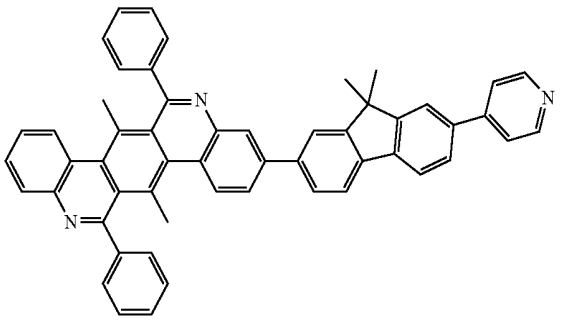

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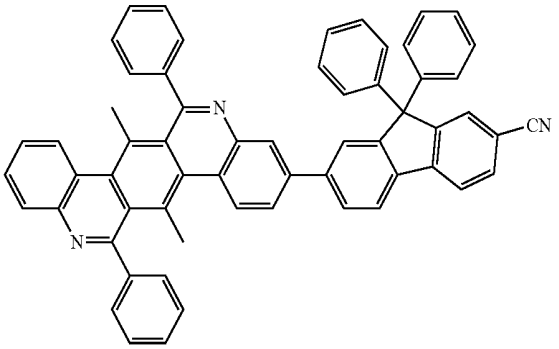

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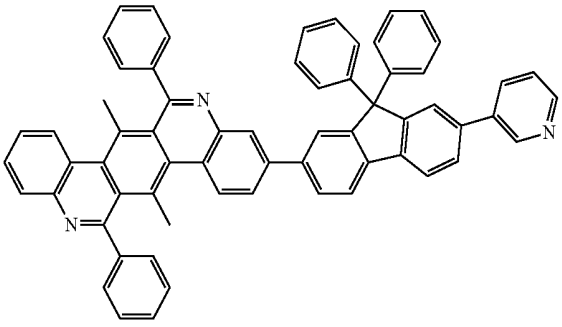

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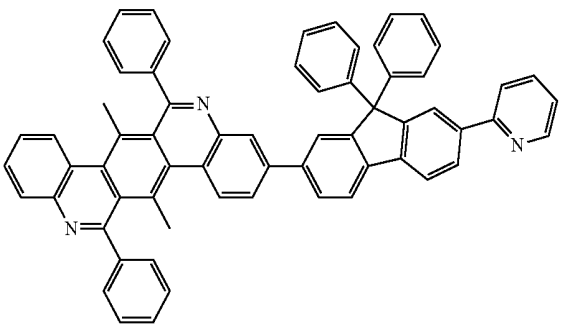

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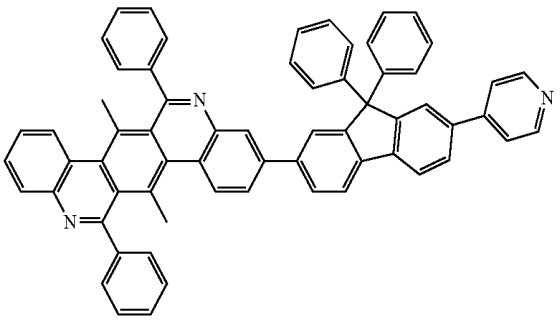

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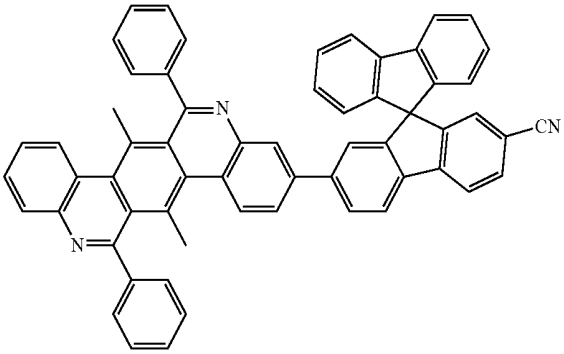

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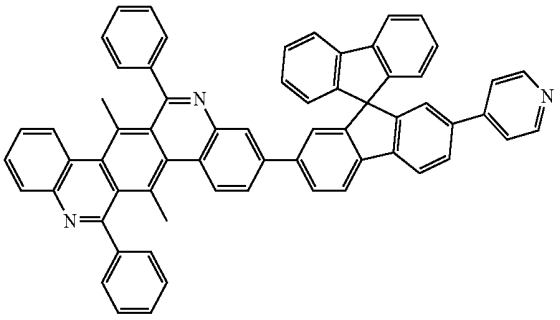

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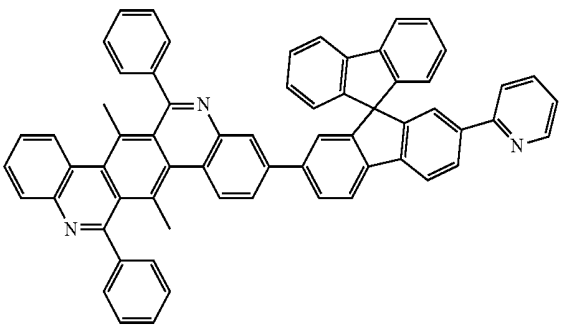

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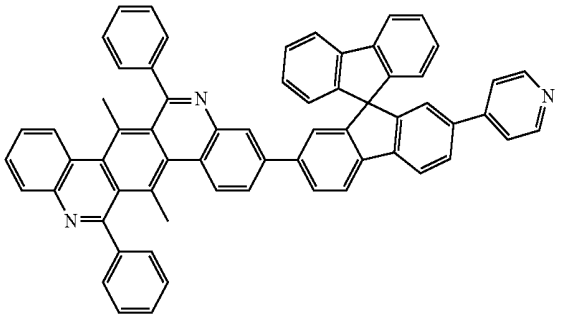

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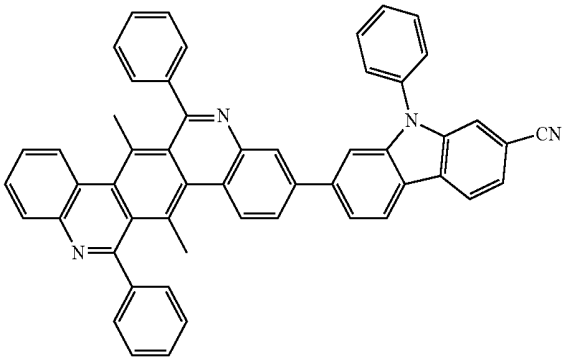

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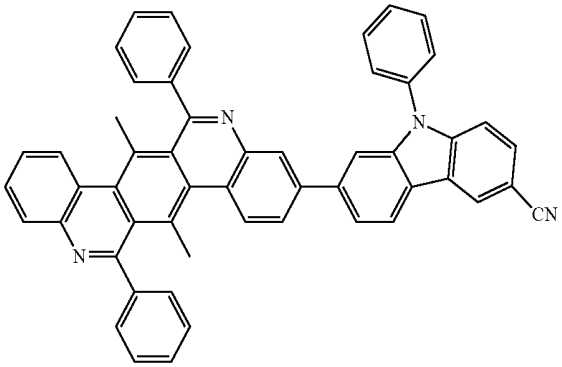

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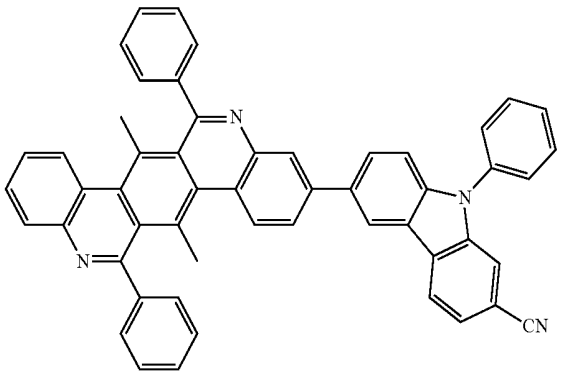

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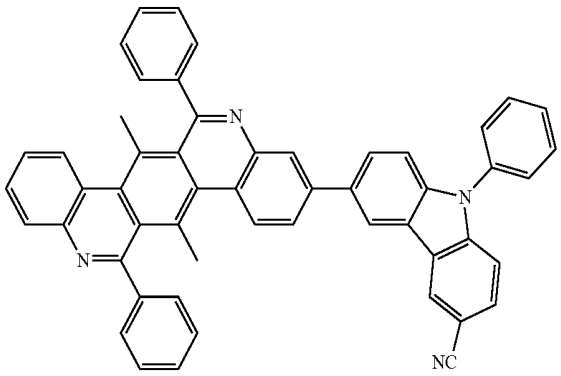

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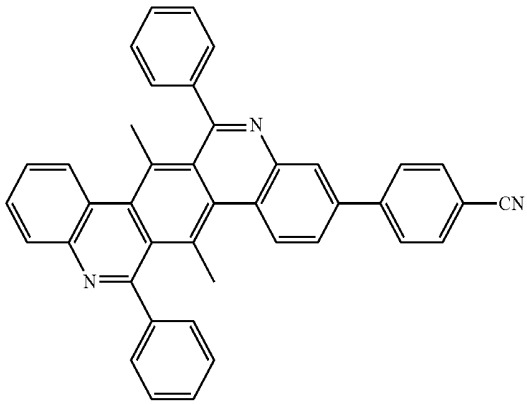

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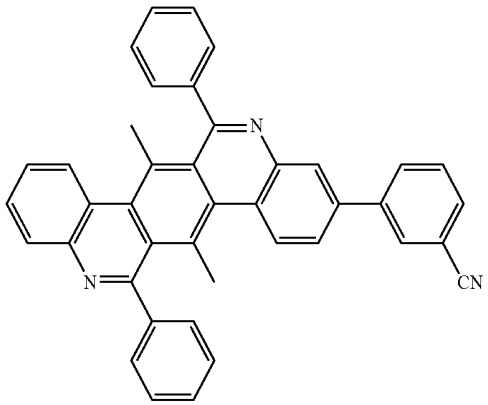

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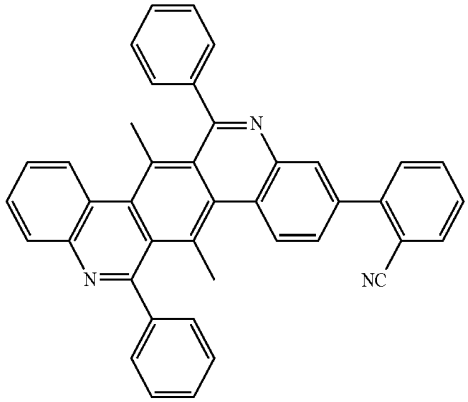

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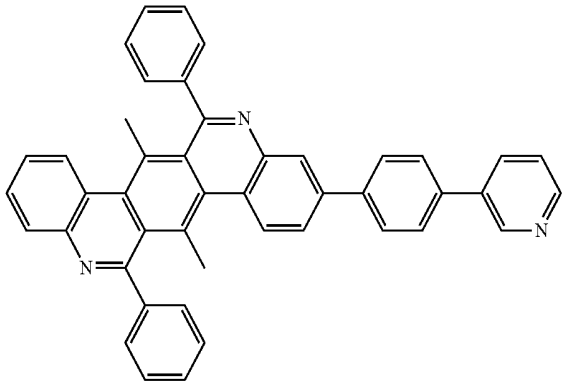

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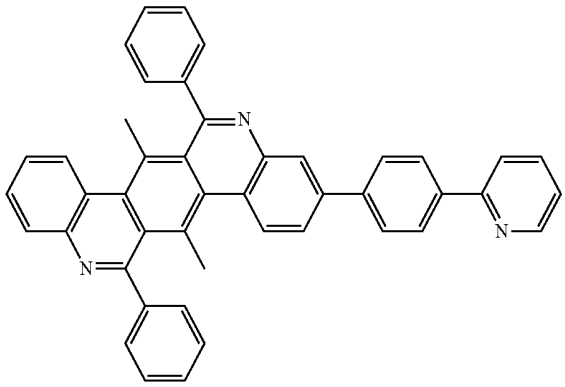

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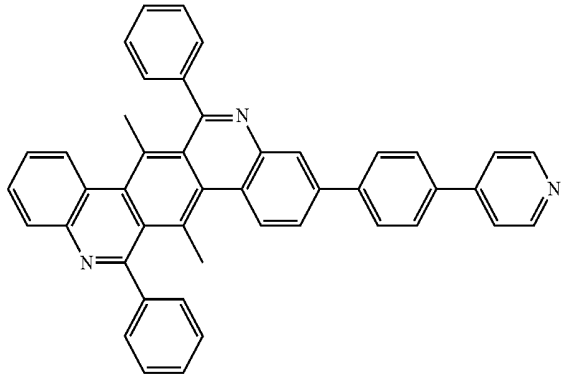

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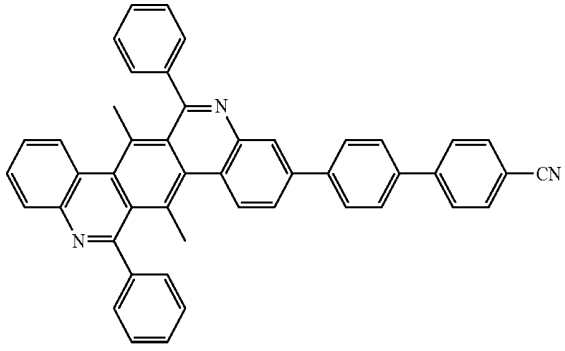

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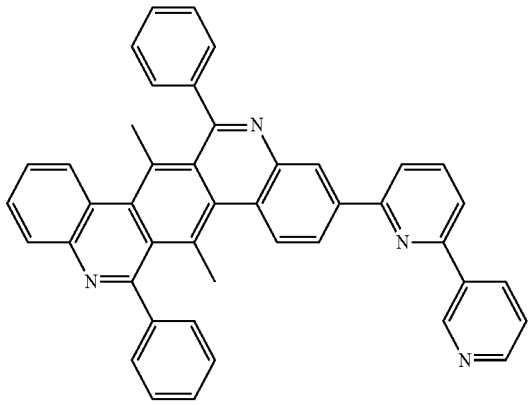

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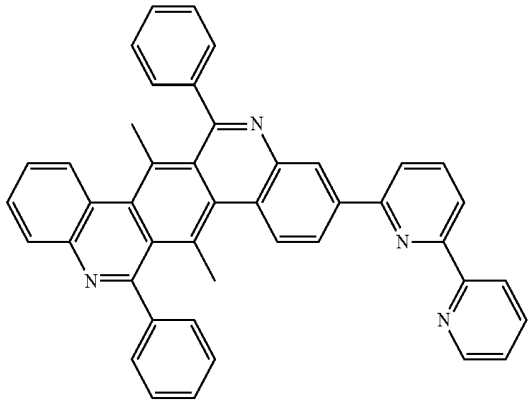

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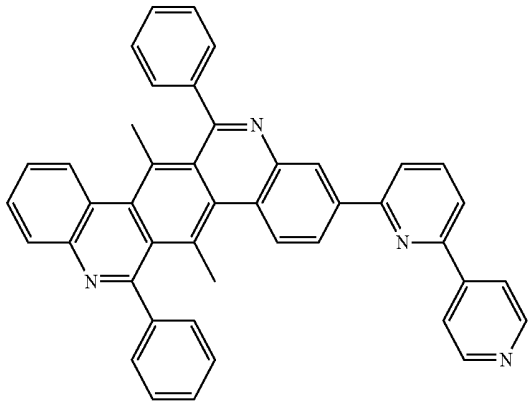

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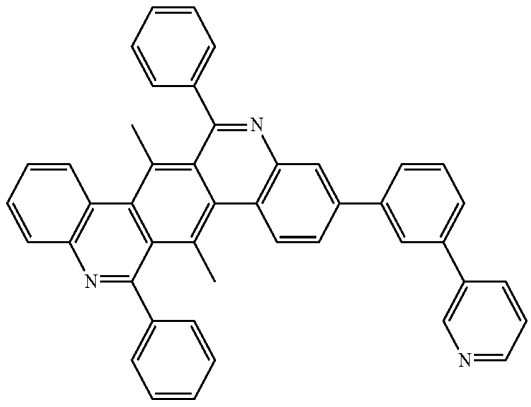

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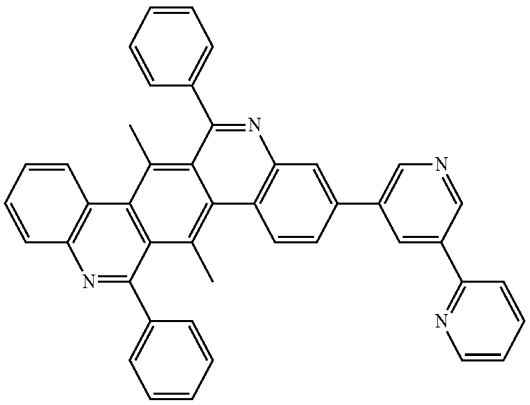

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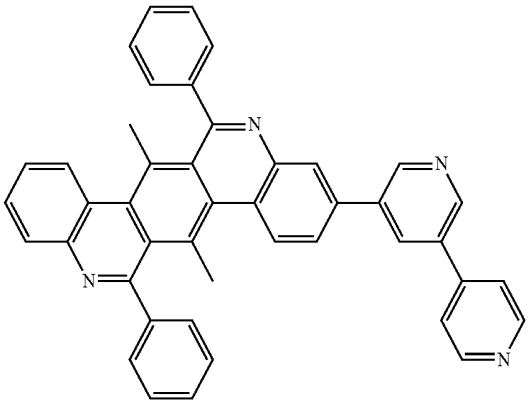

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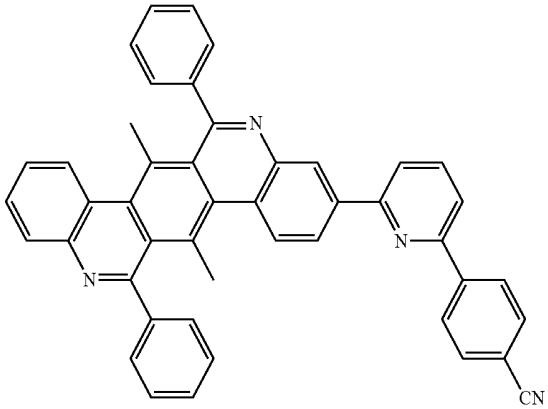

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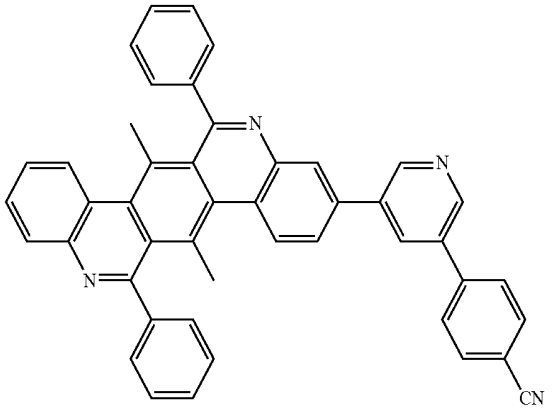

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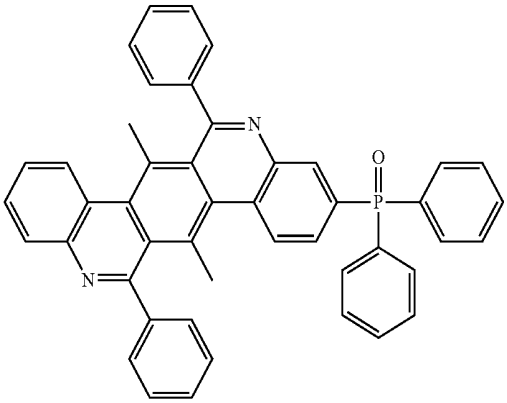

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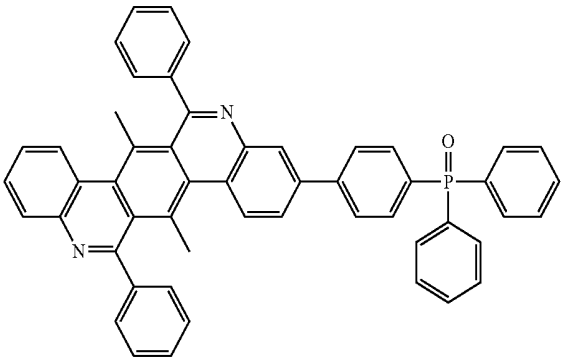

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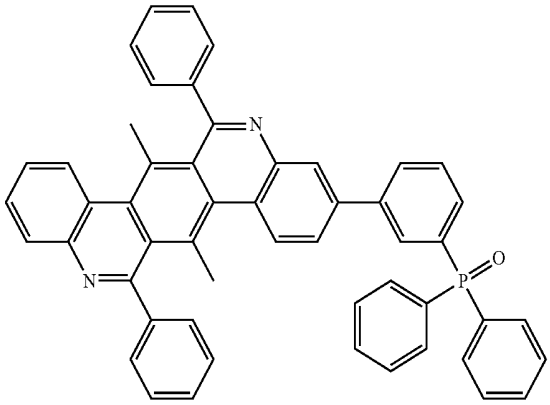

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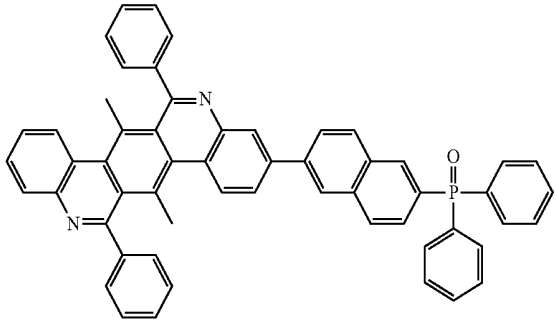

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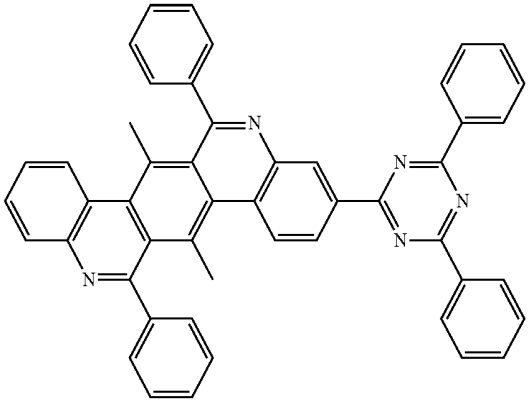

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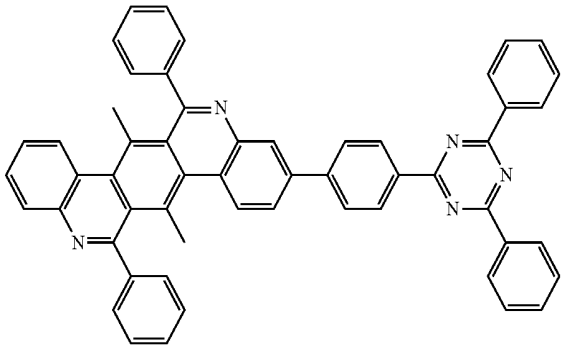

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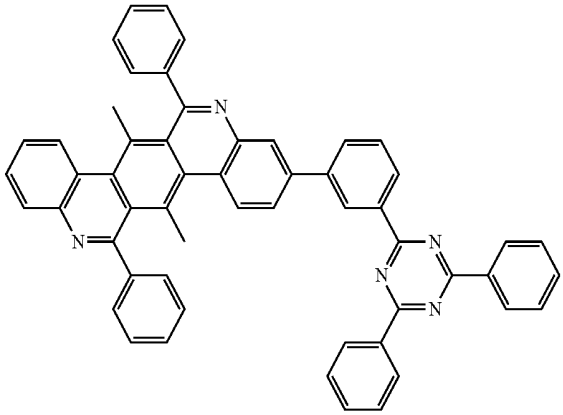

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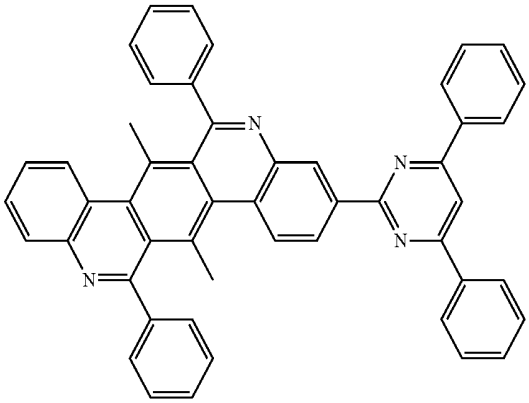

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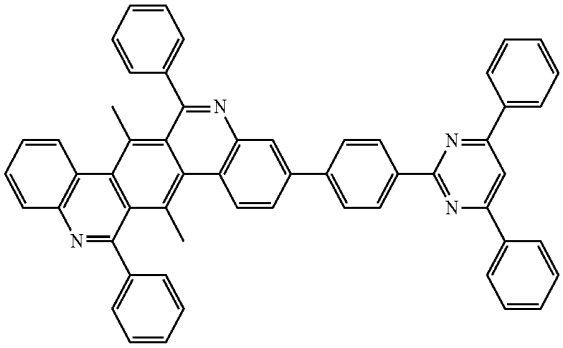

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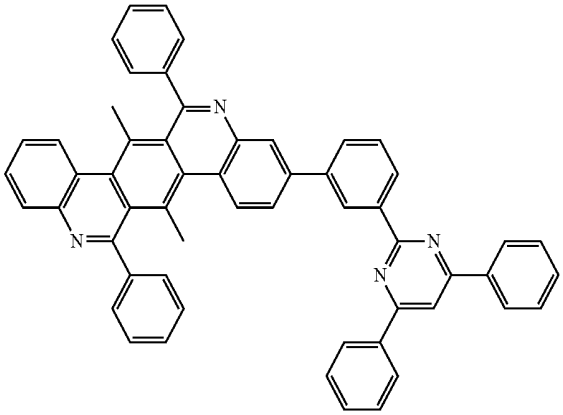

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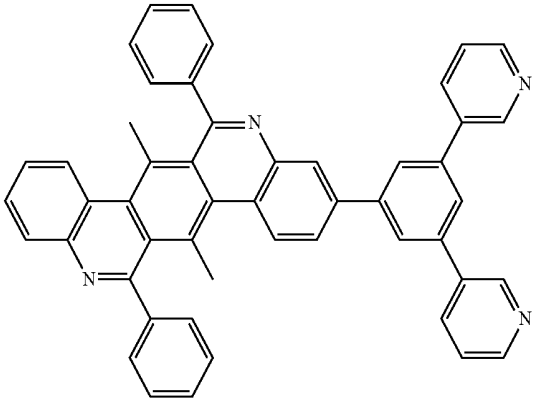

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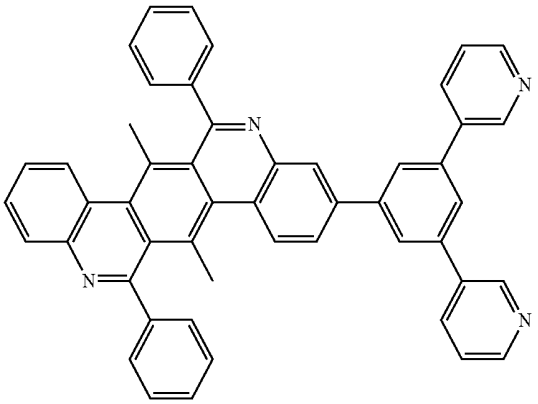

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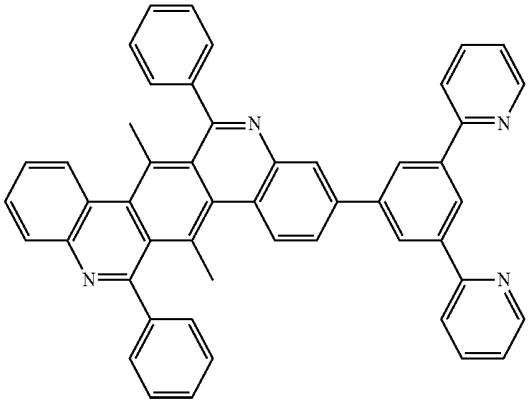

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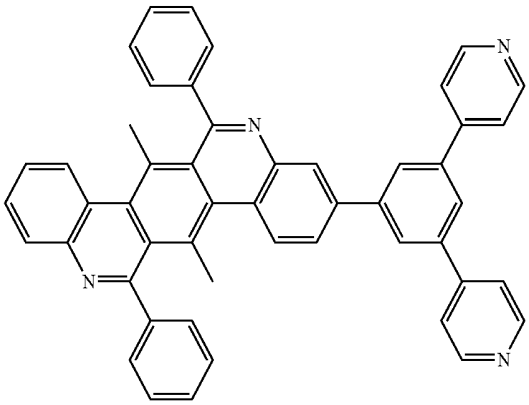

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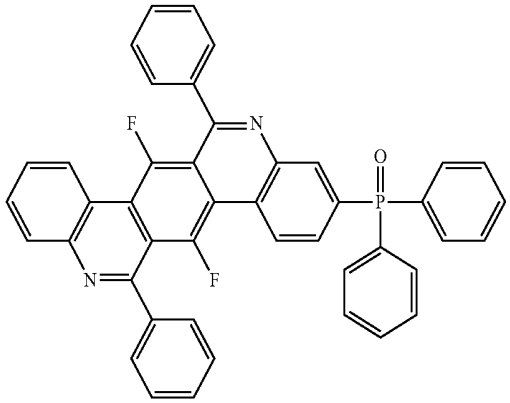

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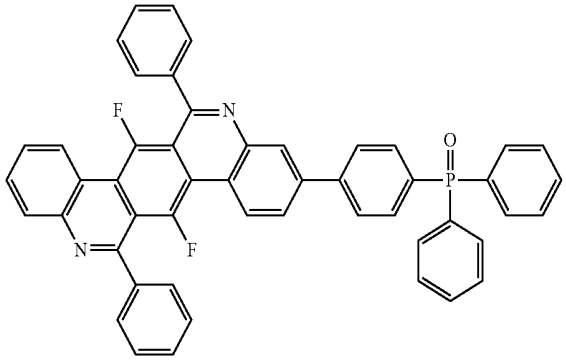

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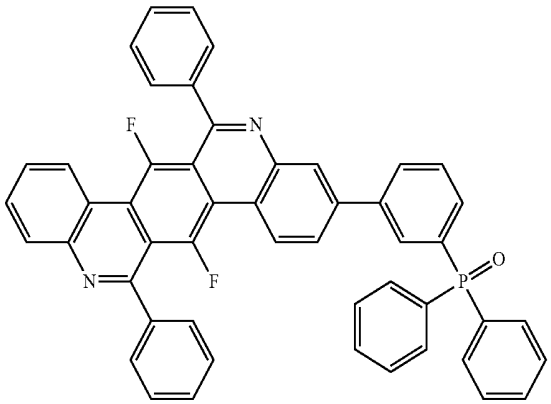

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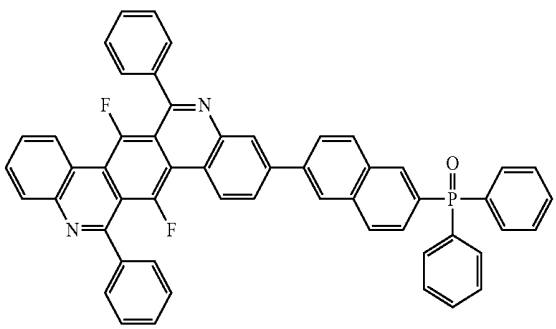

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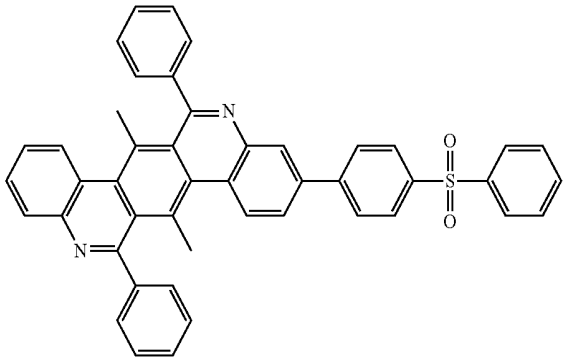

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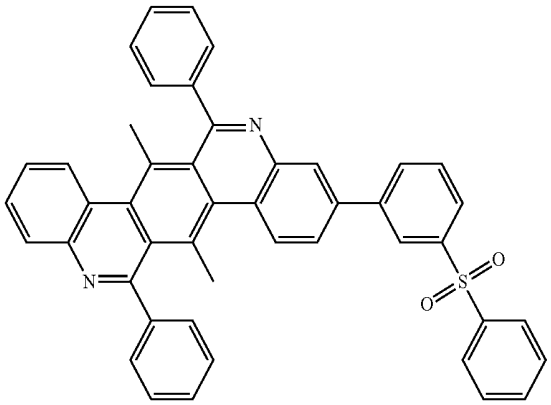

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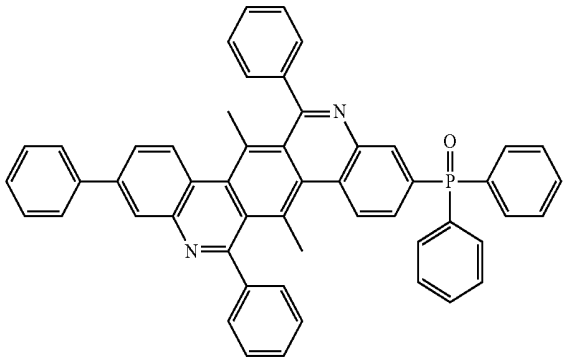

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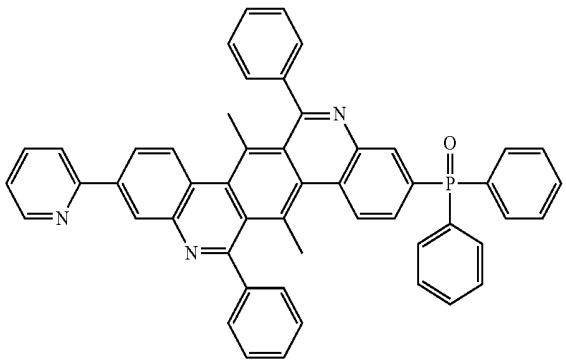

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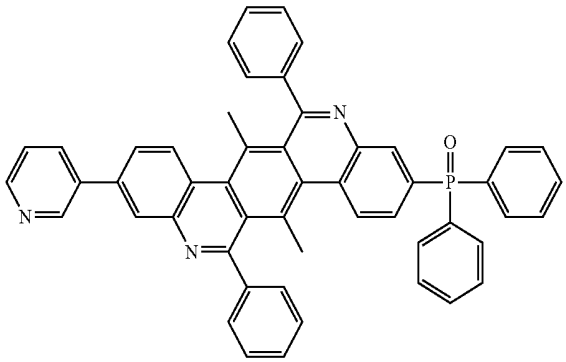

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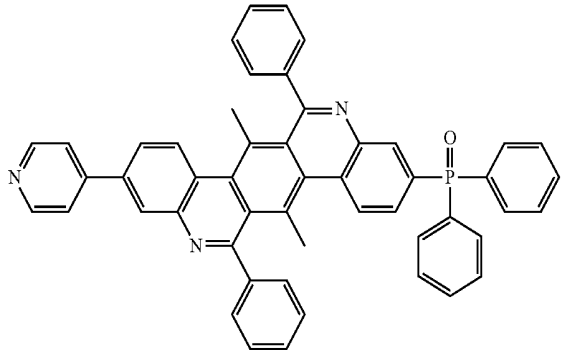

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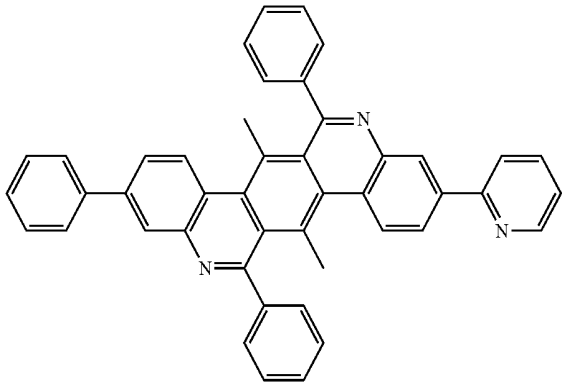

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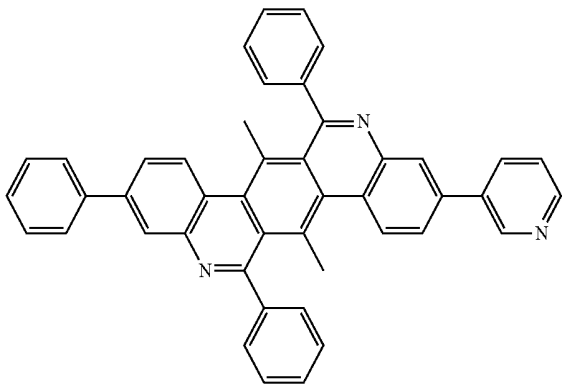

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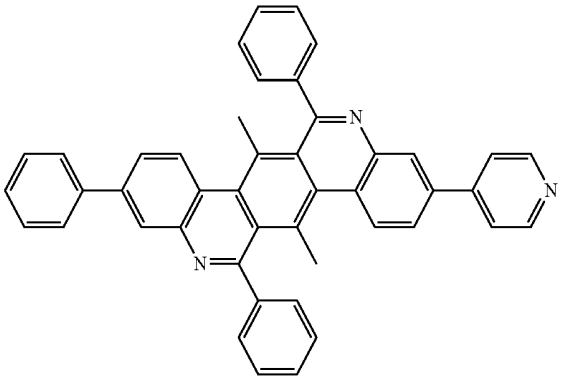

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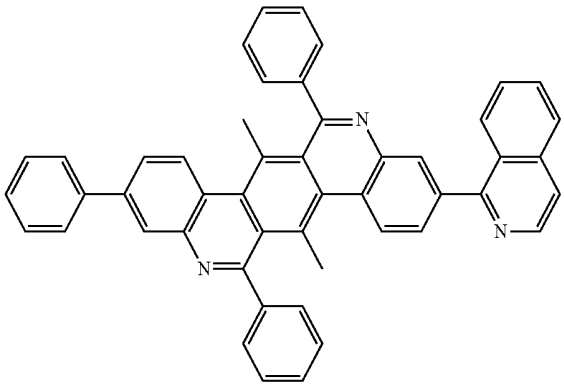

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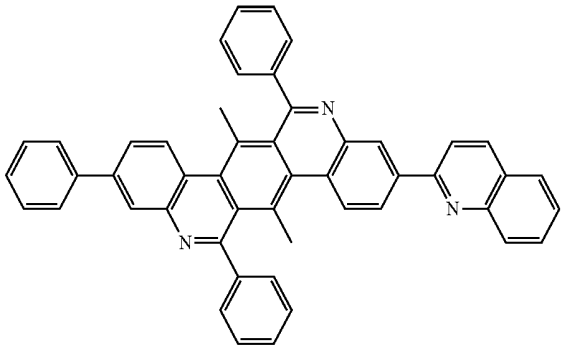

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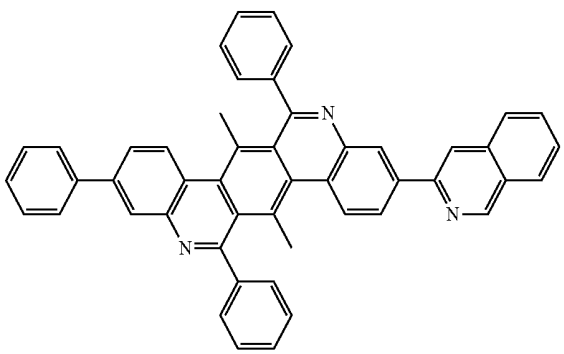

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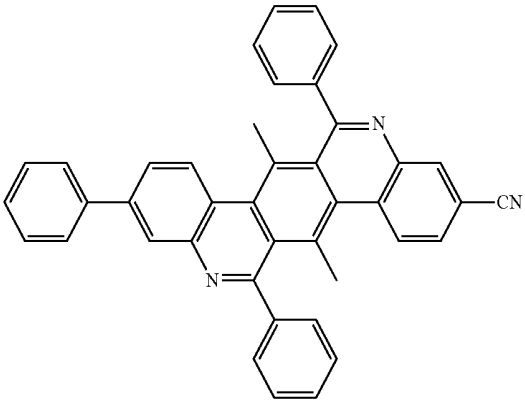

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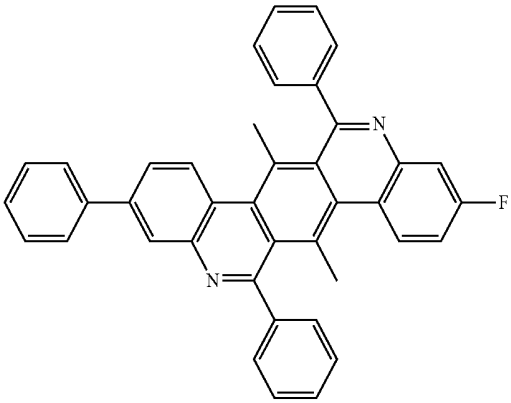

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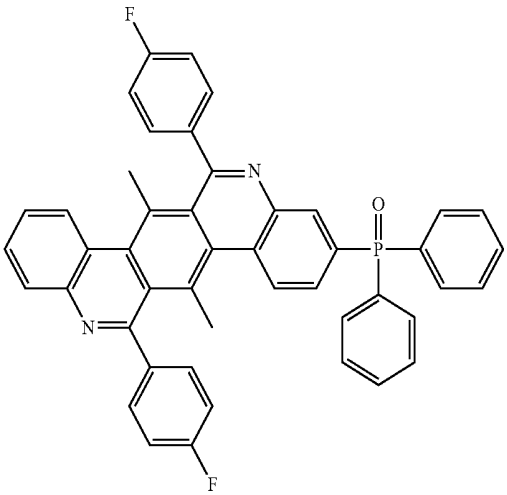

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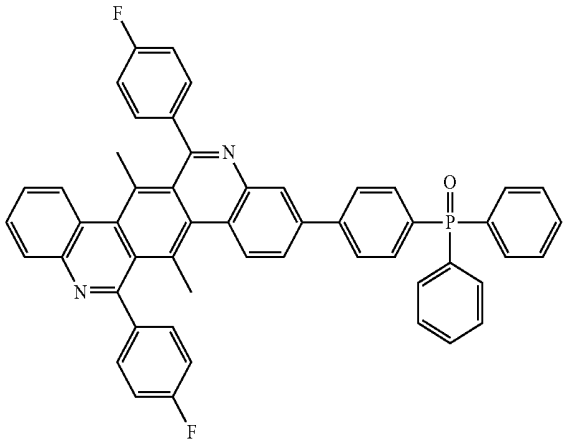

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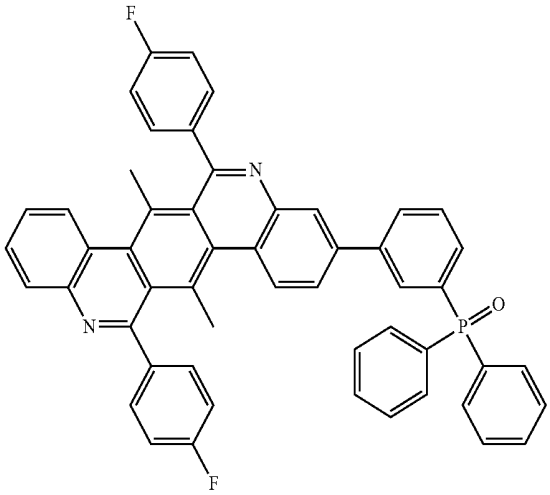

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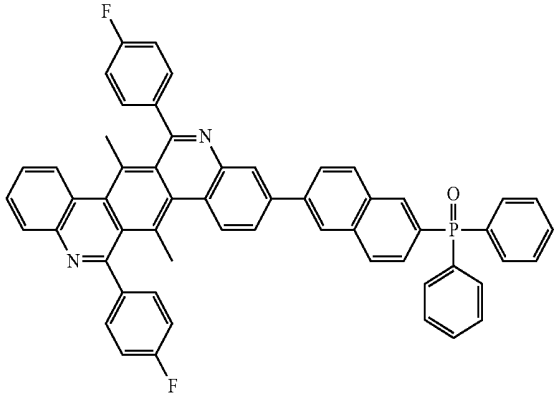

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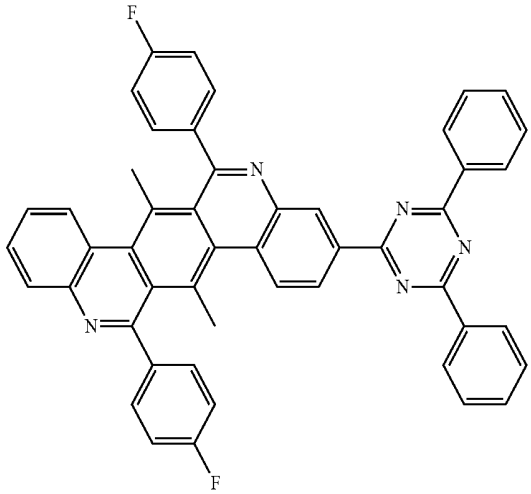

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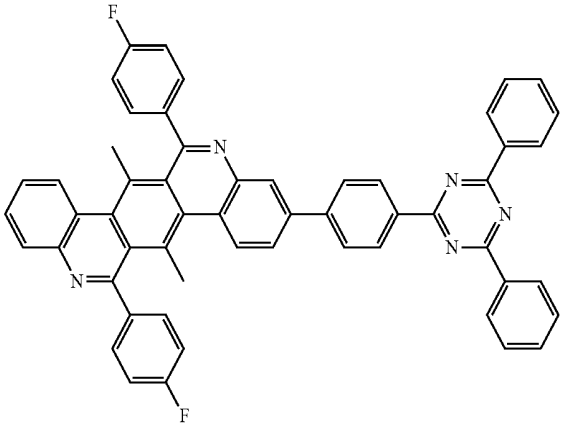

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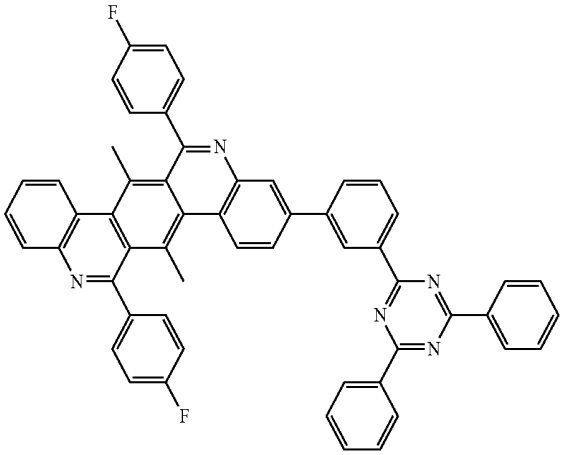

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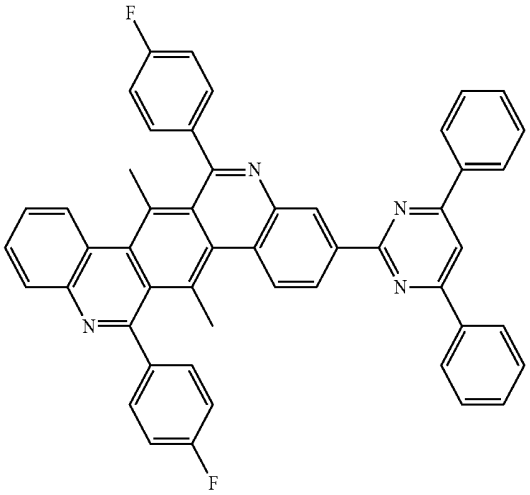

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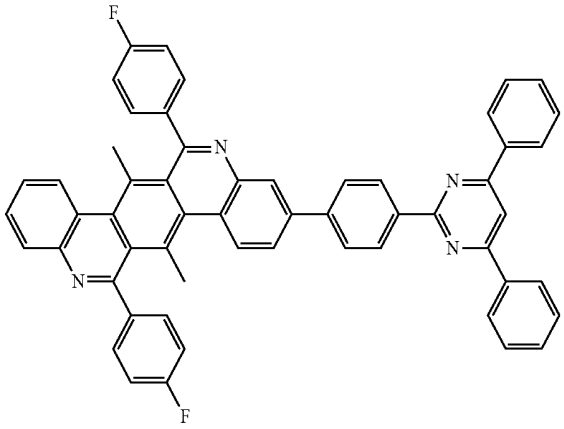

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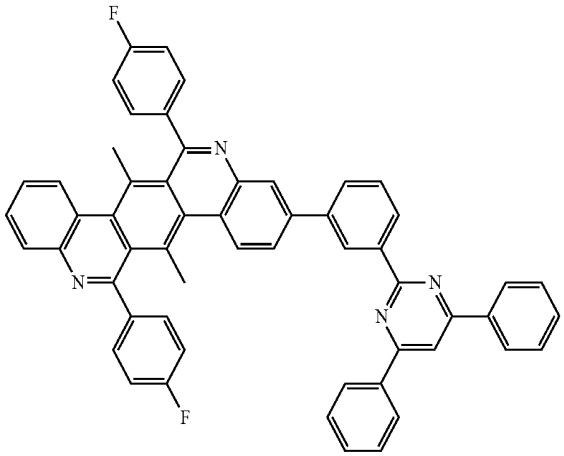

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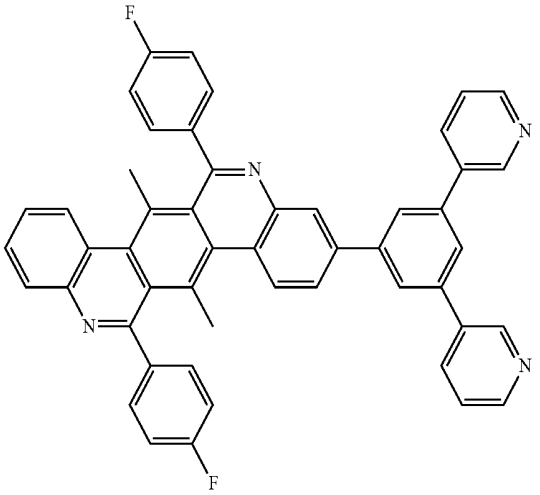

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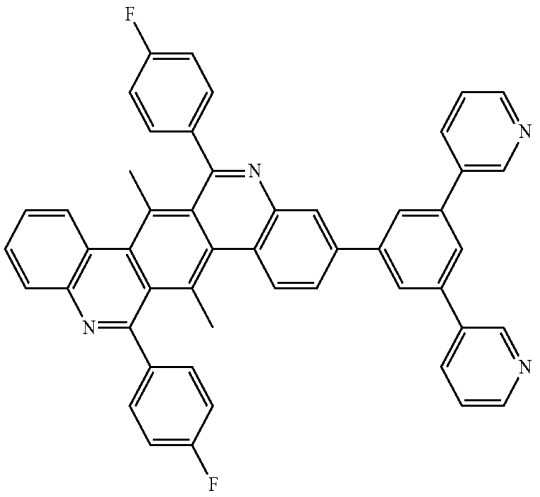

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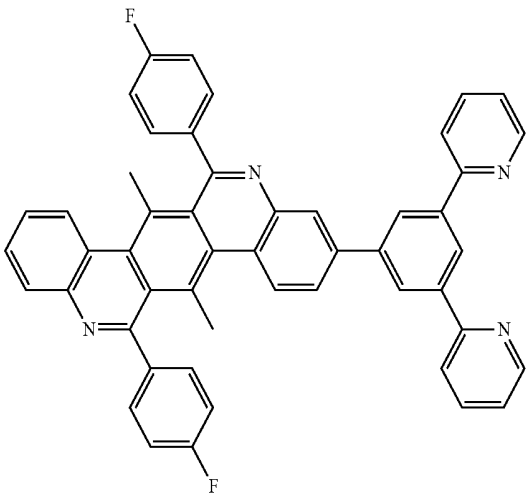

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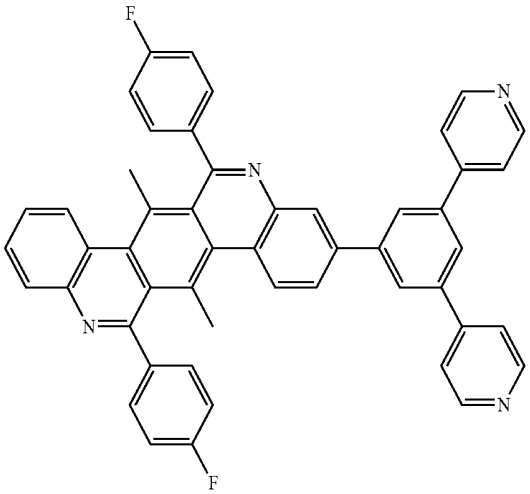

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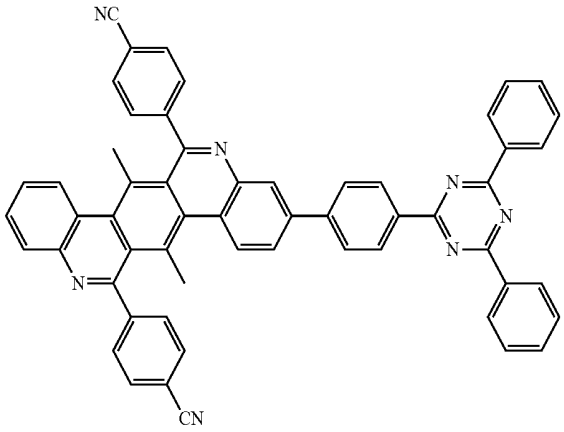

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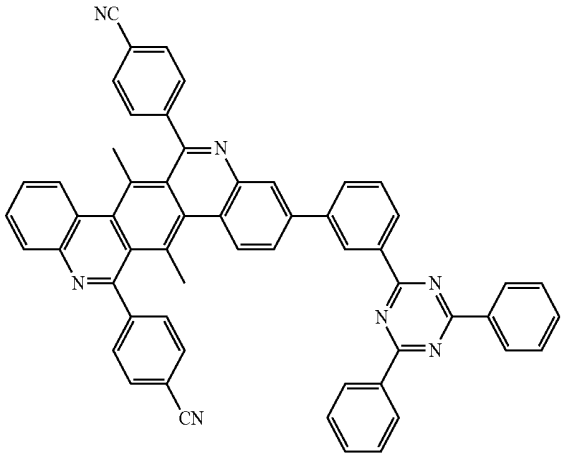

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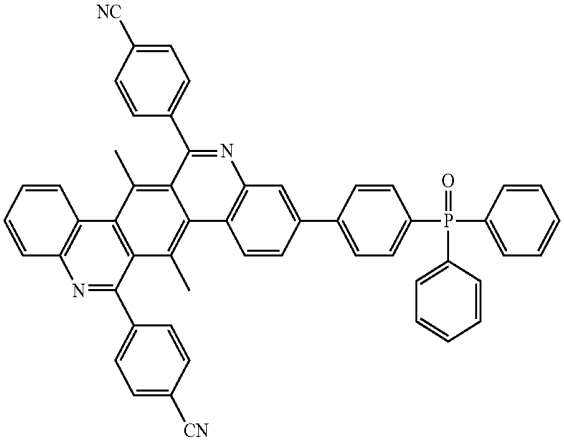

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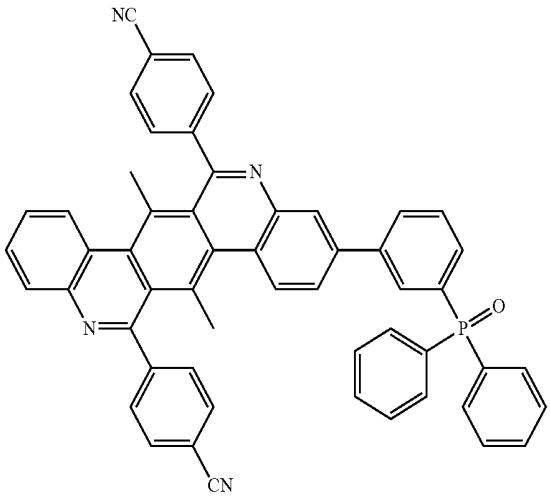

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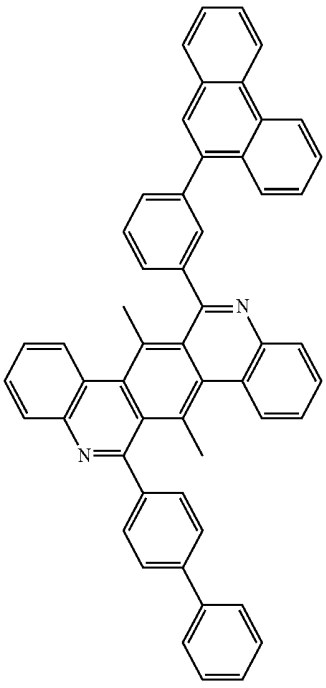

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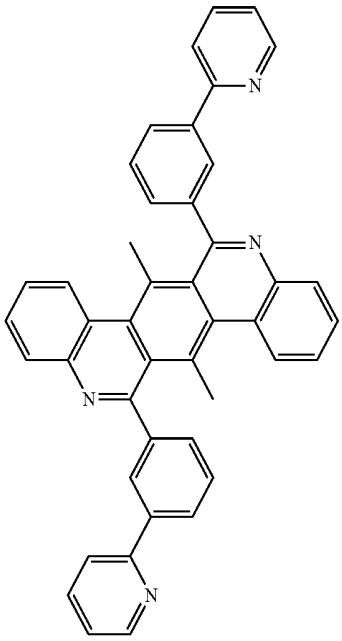

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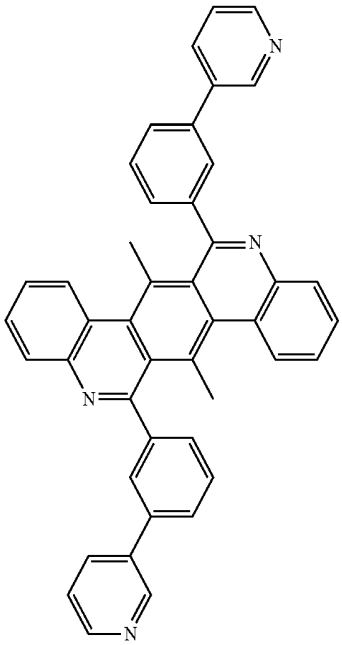

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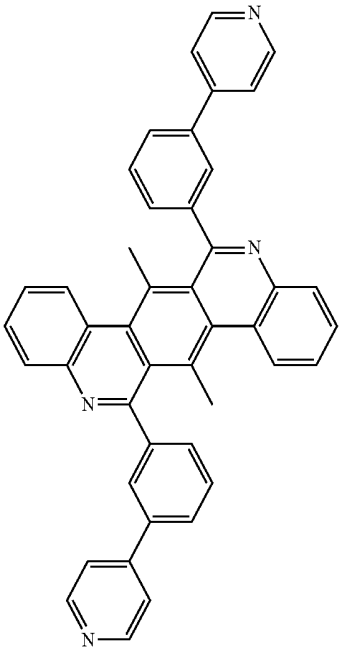

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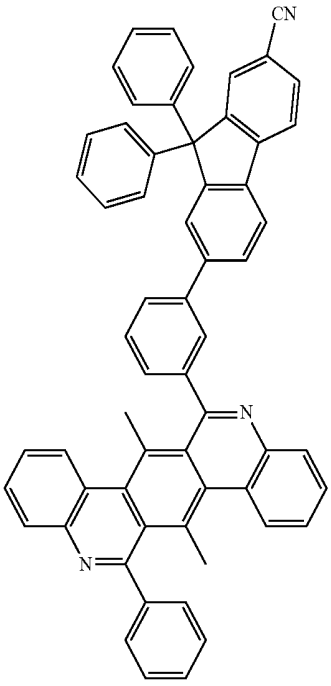

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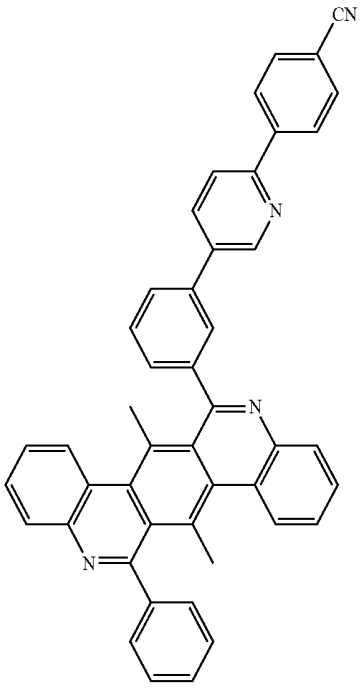

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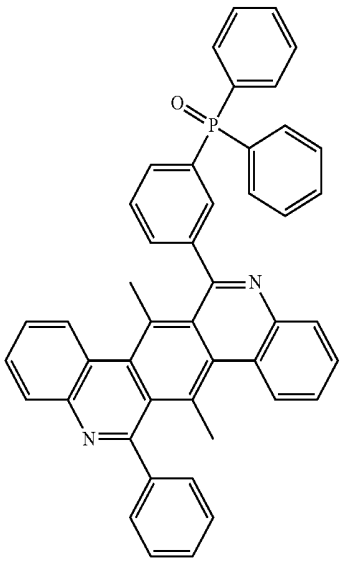

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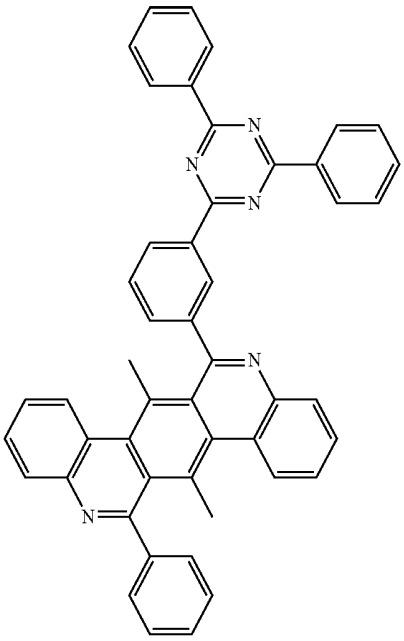

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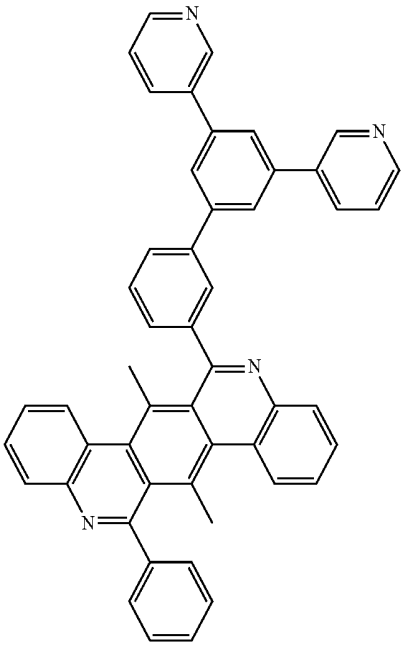

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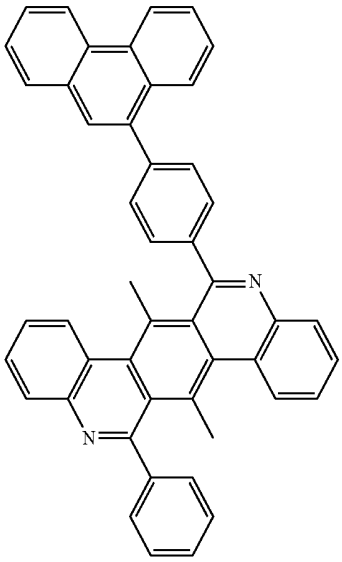

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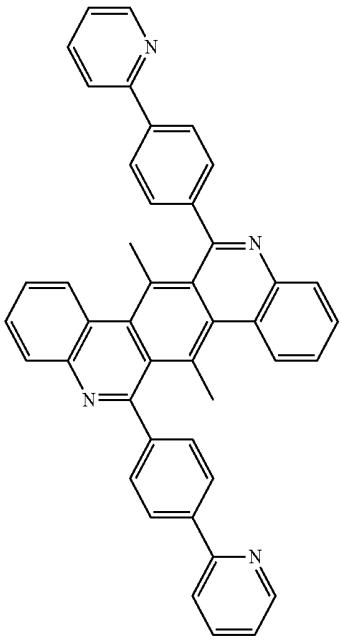

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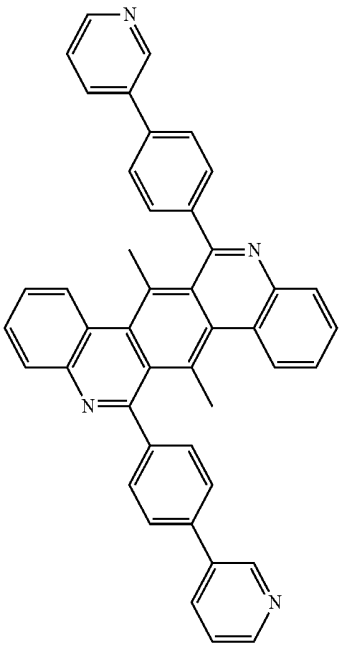

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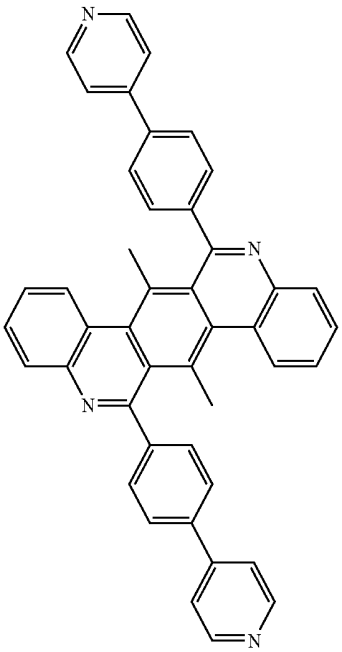

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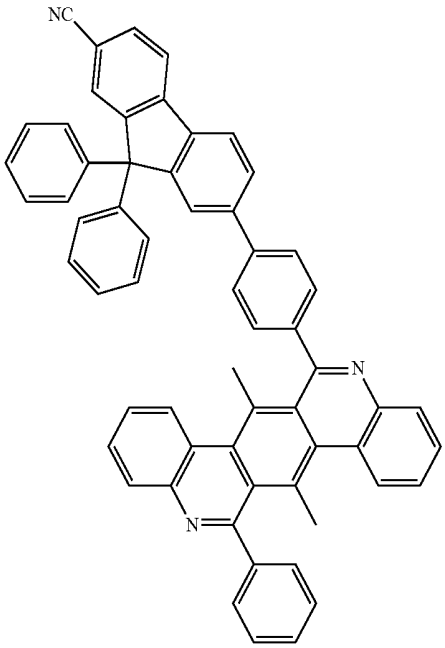

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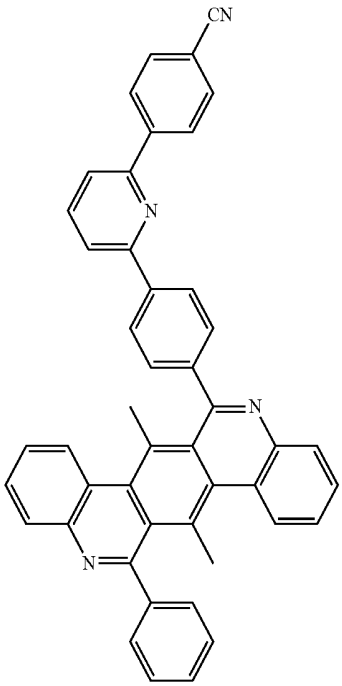

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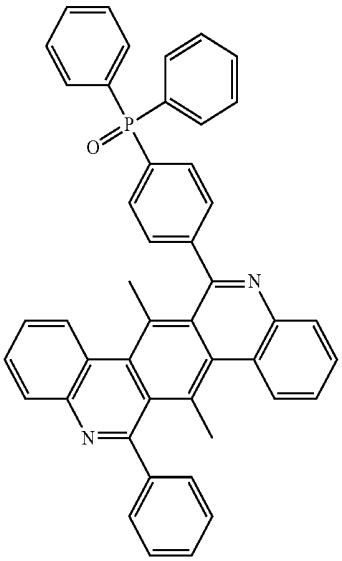

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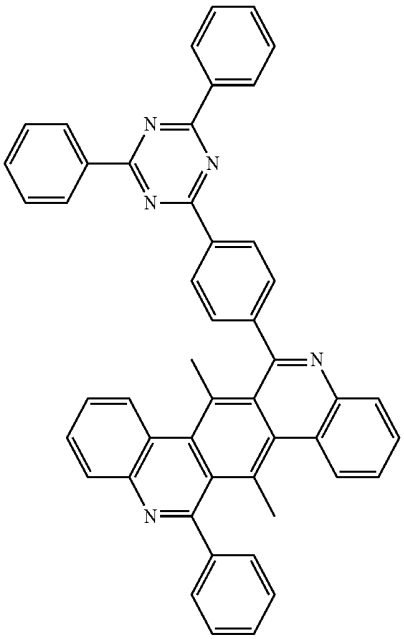

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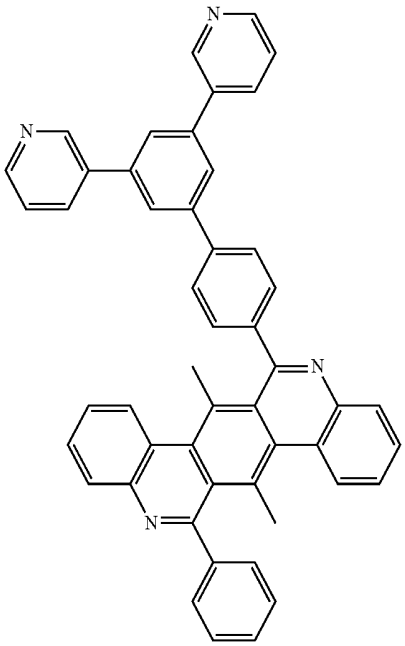

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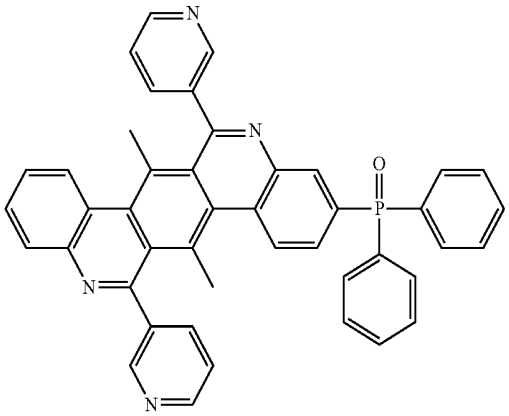

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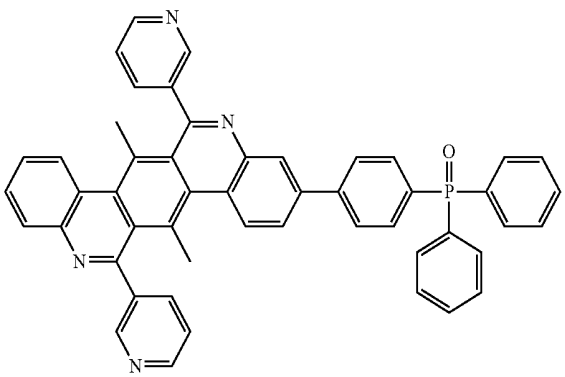

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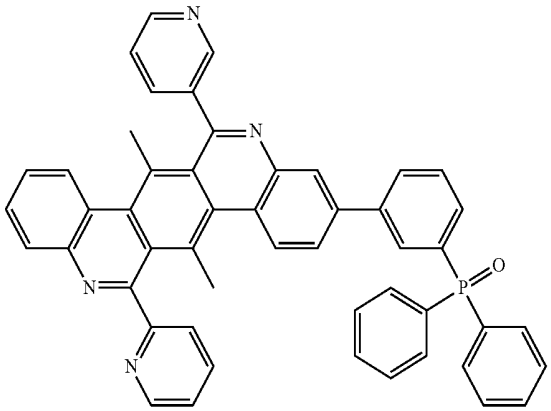

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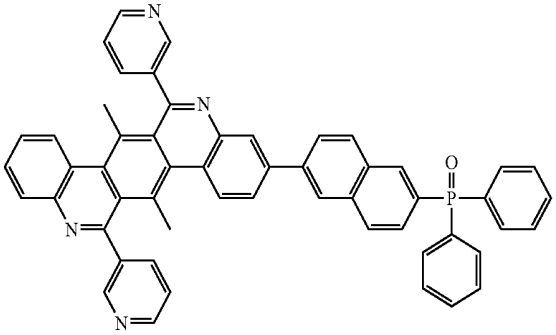

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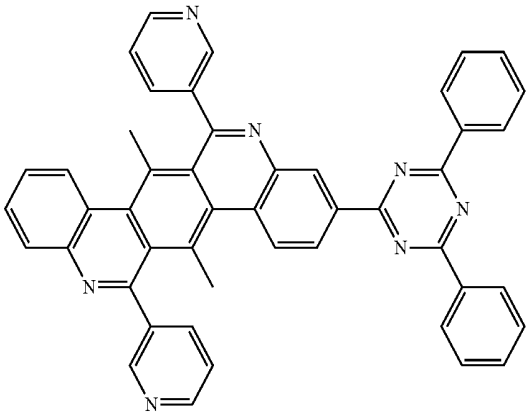

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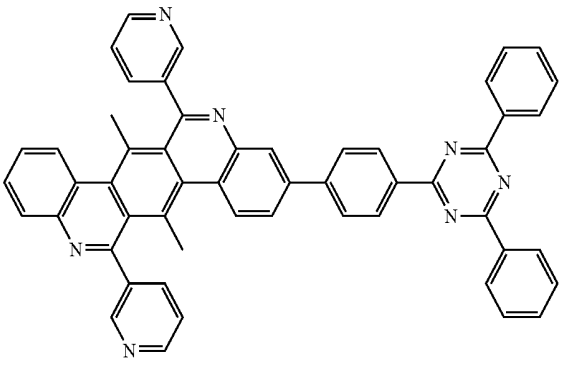

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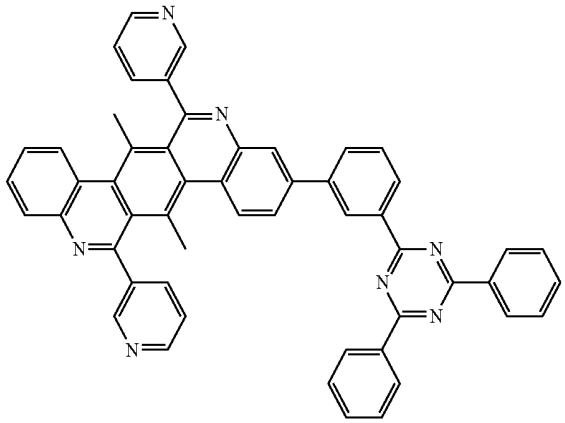

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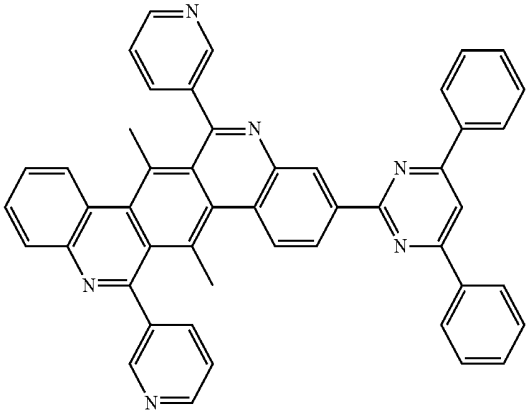

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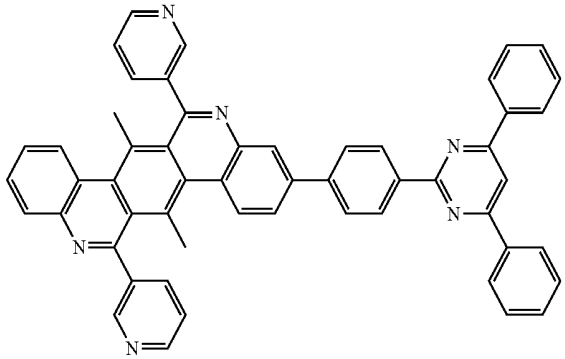

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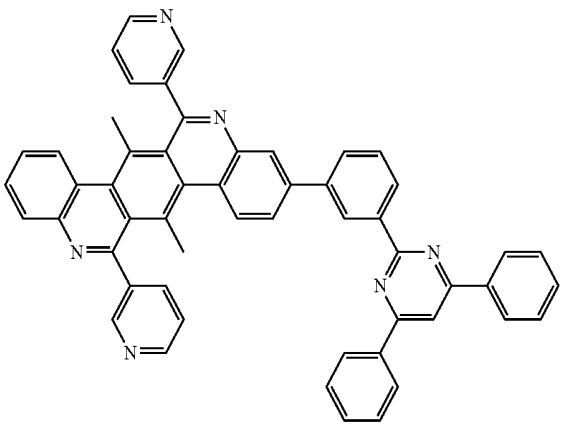

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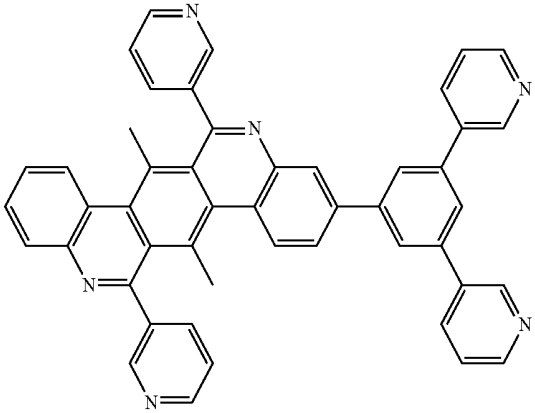

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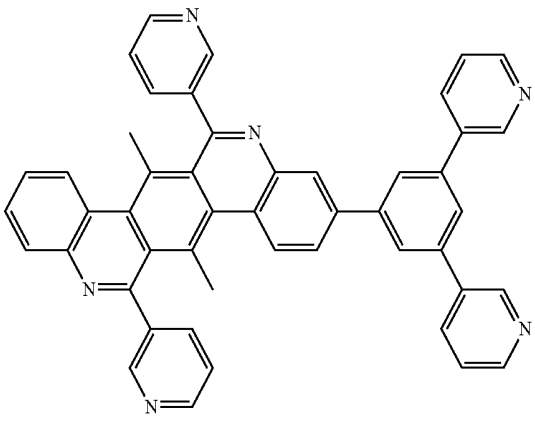

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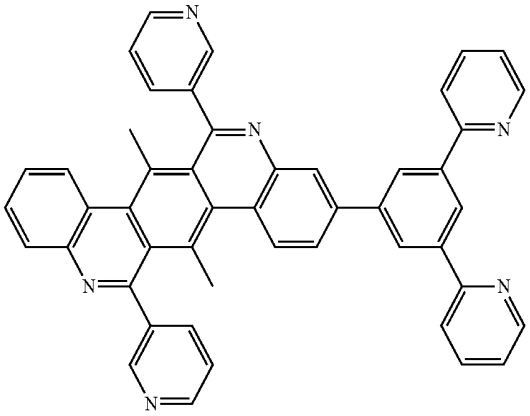

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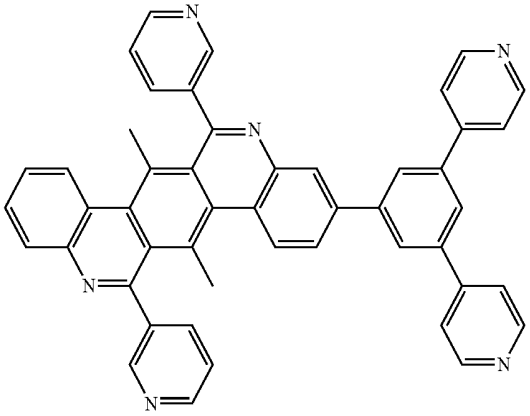

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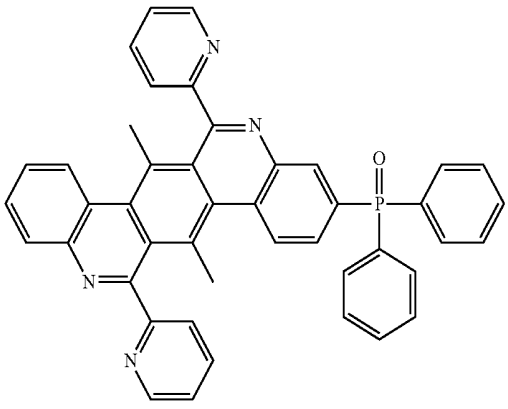

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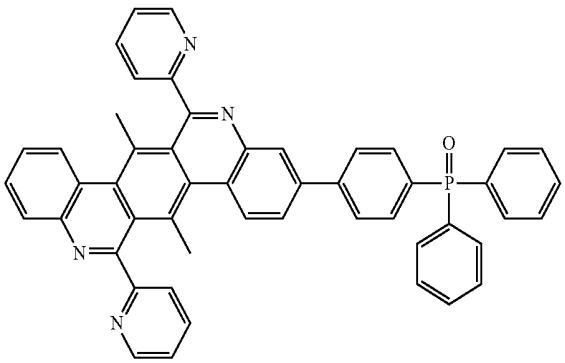

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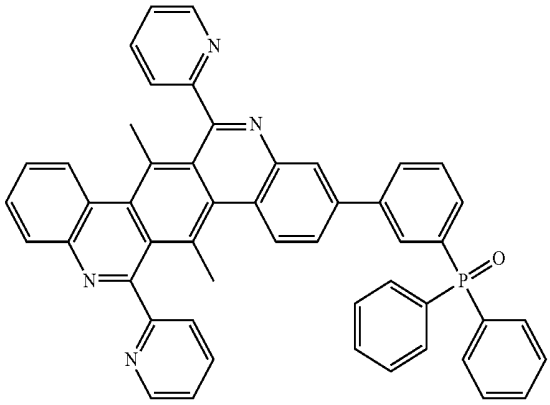

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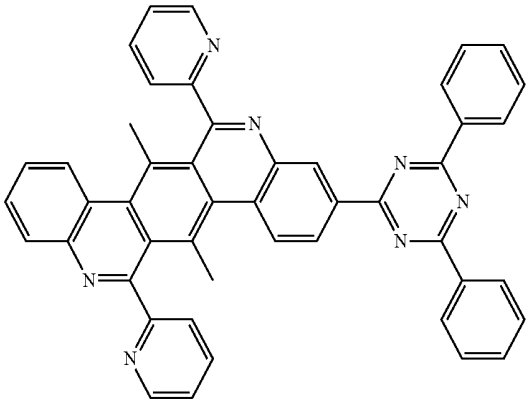

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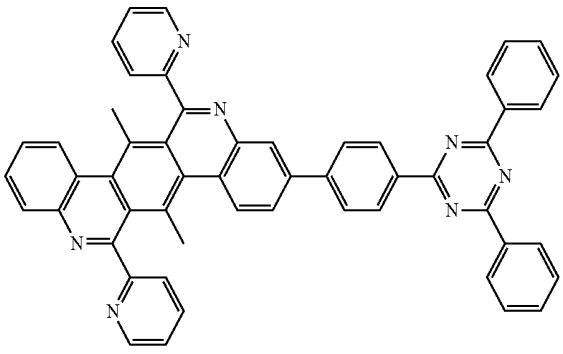
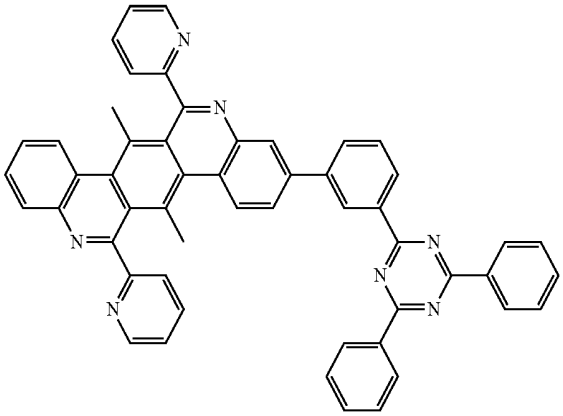


132



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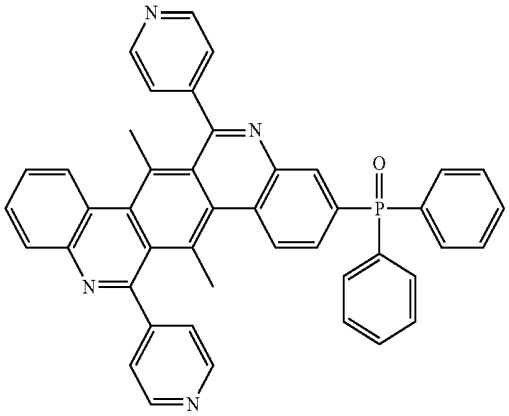
133



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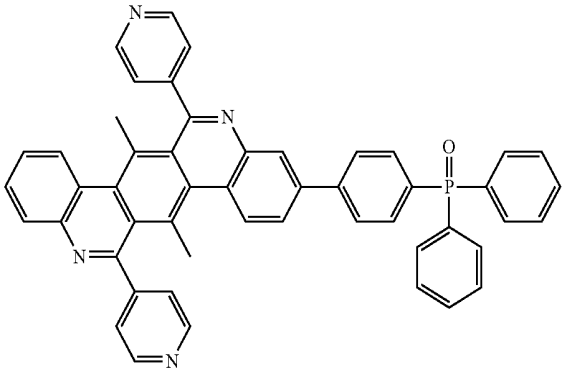

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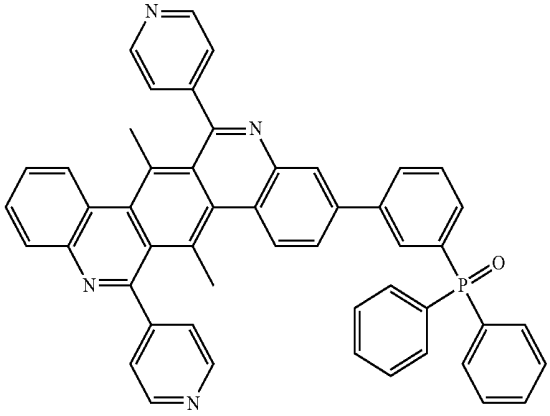

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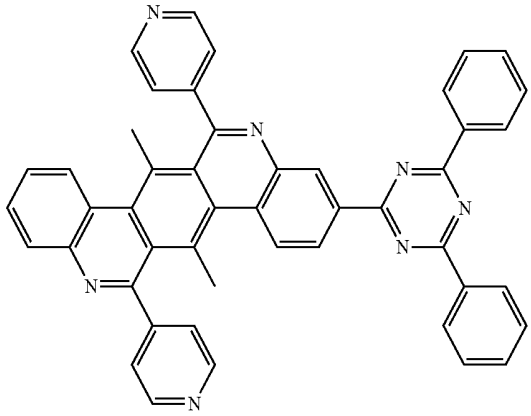
136



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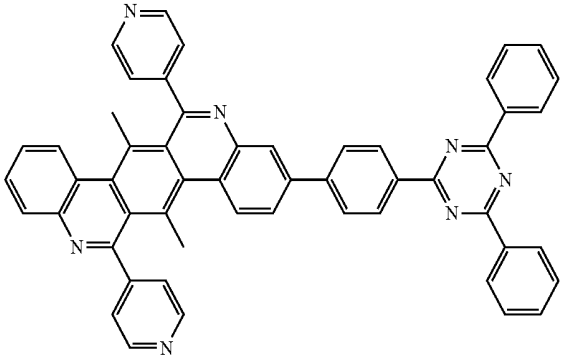

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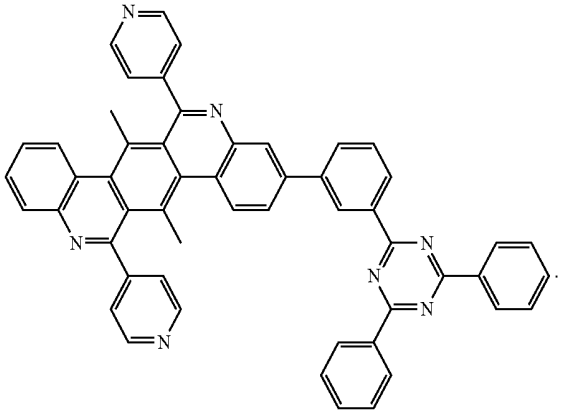

16. An organic light-emitting device, comprising:

a first electrode;

a second electrode facing the first electrode; and

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

wherein the organic layer includes the condensed cyclic compound as claimed in claim **1**.

17. The organic light-emitting device as claimed in claim **16**, wherein:

the first electrode is an anode,

the second electrode is a cathode,

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

the hole transport region includes a hole injection layer, a hole transport layer, an emission auxiliary layer, an electron blocking layer, or a combination thereof, and

the electron transport region includes a buffer layer, a hole blocking layer, an electron control layer, an electron transport layer, an electron injection layer, or a combination thereof.

18. The organic light-emitting device as claimed in claim **17**, wherein the electron transport region includes the condensed cyclic compound.

19. The organic light-emitting device as claimed in claim **17**, wherein:

the electron transport region includes the electron transport layer, and

the electron transport layer includes the condensed cyclic compound.

20. The organic light-emitting device as claimed in claim **17**, wherein:

the hole transport region includes a p-dopant, and

a lowest unoccupied molecular orbital (LUMO) energy level of the p-dopant is −3.5 eV or less.

* * * * *

专利名称(译)	缩合环状化合物和包括其的有机发光器件		
公开(公告)号	US20180166635A1	公开(公告)日	2018-06-14
申请号	US15/628688	申请日	2017-06-21
[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	JEONG EUNJAE PARK JUNHA SIM MUNKI LEE HYOYOUNG KIM YOUNGKOOK HWANG SEOKHWAN		
发明人	JEONG, EUNJAE PARK, JUNHA SIM, MUNKI LEE, HYOYOUNG KIM, YOUNGKOOK HWANG, SEOKHWAN		
IPC分类号	H01L51/00 H01L51/50 C07D471/06 C07D221/18		
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优先权	1020160168009 2016-12-09 KR		
其他公开文献	US10693083		
外部链接	Espacenet USPTO		

摘要(译)

缩合环状化合物和包含其的有机发光装置，缩合环状化合物由式1表示：