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

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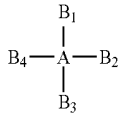
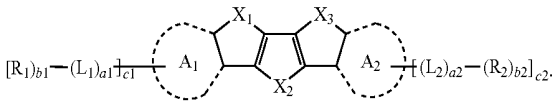
(57) **ABSTRACT**

A condensed cyclic compound that emits high-efficiency delayed fluorescence is provided. The compound may be represented by Formula 1, in which A is a moiety represented by Formula 1-1. In Formula 1-1, X_1 may be a carbon or silicon atom linked to B_1 and B_2, and X_2 may be a carbon or silicon atom linked to B_3 and B_4.

Formula 1



Formula 1-1



When the compound represented by Formula 1 satisfies $E_{S1}<2E_{T1}<E_{T2}$ (wherein E_{S1} is the first singlet energy level, E_{T1} is the first triplet energy level, and E_{T2} is the second triplet energy level of the condensed cyclic compound), an energy transition to a second triplet state may be disfavored during up-conversion of the condensed cyclic compound from a triplet state to a singlet state through interaction with an adjacent molecule in a triplet energy state.

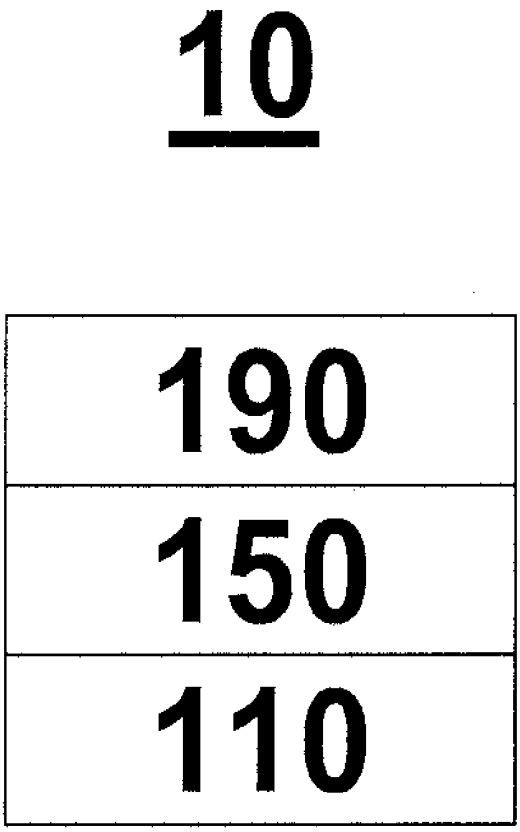


FIG. 1

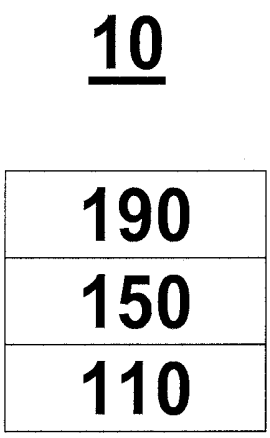


FIG. 2

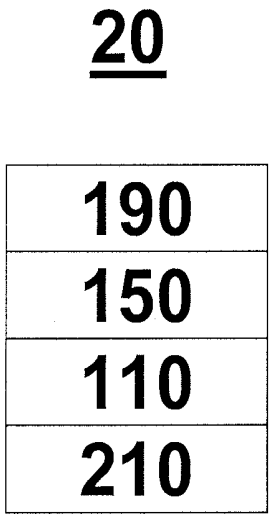


FIG. 3

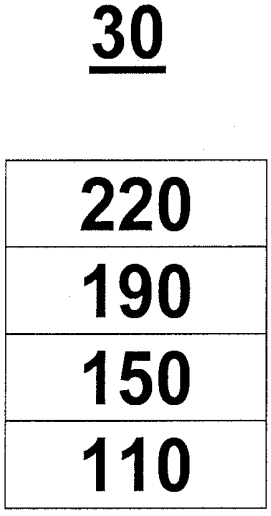
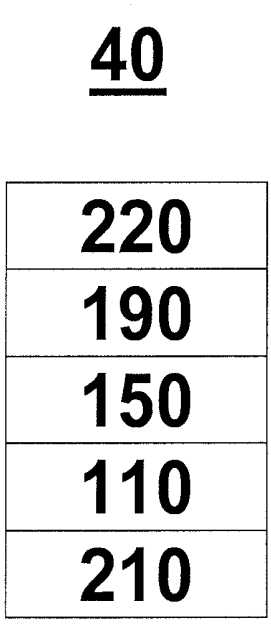


FIG. 4



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

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to and the benefit of Korean Patent Application No. 10-2017-0166645, filed on Dec. 6, 2017, in the Korean Intellectual Property Office, the entire content of which is incorporated herein by reference.

BACKGROUND

1. Field

[0002] One or more aspects of example embodiments of the present disclosure relate to a condensed cyclic compound and an organic light-emitting device including the same.

2. Description of the Related Art

[0003] Organic light-emitting devices are self-emission devices that produce full-color images, and may also 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 related art.

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

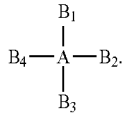
SUMMARY

[0005] One or more aspects of example embodiments of the present disclosure provide a condensed cyclic compound and an organic light-emitting device including the same.

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

[0007] One or more aspects of example embodiments of the present disclosure provide a condensed cyclic compound represented by Formula 1:

Formula 1

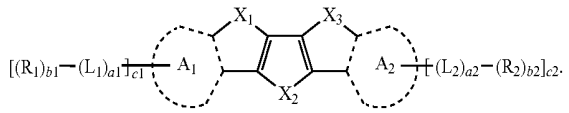


[0008] In Formula 1,

[0009] A may be a moiety represented by Formula 1-1, and

[0010] B_1 to B_4 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:

Formula 1-1



[0011] In Formula 1-1,

[0012] X_1 may be a carbon atom linked to B_1 and B_2 or a silicon atom linked to B_1 and B_2,

[0013] X_2 may be a carbon atom linked to B_3 and B_4 or a silicon atom linked to B_3 and B_4,

[0014] X_3 may be O or S,

[0015] A_1 and A_2 may each independently be a benzene group, a pyridine group, a pyrimidine group, a pyridazine group, or a pyrazine group,

[0016] L_1 and L_2 may each independently be a substituted or unsubstituted C_5-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group,

[0017] a1 and a2 may each independently be an integer from 0 to 5,

[0018] R_1 and R_2 may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_{60} alkynyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —$Si(Q_1)(Q_2)(Q_3)$, —$B(Q_1)(Q_2)$, —$C(=O)(Q_1)$, —$N(Q_1)(Q_2)$, —$P(=O)(Q_1)(Q_2)$, —$P(=O)_2(Q_1)$, —$P(=S)(Q_1)(Q_2)$, —$P(=S)_2(Q_1)$, —$S(=O)(Q_1)(Q_2)$, and —$S(=O)_2(Q_1)(Q_2)$,

[0019] b1 and b2 may each independently be an integer from 1 to 10,

[0020] c1 and c2 may each independently be 1, 2, 3, or 4,

[0021] at least one substituent of the substituted C_5-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 may be selected from:

[0022] 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;

[0023] 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 $—P(=O)(Q_{11})(Q_{12})$;

[0024] 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; and

[0025] 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 $—P(=O)(Q_{21})(Q_{22})$; and

[0026] $—Si(Q_{31})(Q_{32})(Q_{33})$, $—N(Q_{31})(Q_{32})$, $—B(Q_{31})(=O)$, $—C(=O)(Q_{31})$, $—S(=O)_2(Q_{31})$, and $—P(=O)(Q_{31})(Q_{32})$, and

[0027] Q_1 to Q_3, Q_{11} to Q_{13}, Q_{21} to Q_{23}, and Q_{31} to Q_{33} may each independently be selected from hydrogen, deuterium, —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.

[0028] Another aspect provides an organic light-emitting device including: a first electrode; a second facing the first electrode; and an organic layer between the first electrode and the second electrode, wherein the organic layer includes an emission layer and at least one of the condensed cyclic compound represented by Formula 1.

BRIEF DESCRIPTION OF THE DRAWINGS

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

[0030] FIG. **1** is a schematic view of an organic light-emitting device according to an embodiment of the present disclosure;

[0031] FIG. **2** is a schematic view of an organic light-emitting device according to an embodiment of the present disclosure;

[0032] FIG. **3** is a schematic view of an organic light-emitting device according to an embodiment of the present disclosure; and

[0033] FIG. **4** is a schematic view of an organic light-emitting device according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0034] The present disclosure will now be described more fully with reference to example embodiments. The disclosure may, however, be embodied in many different forms and should not be construed as being 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 the concept of the disclosure to those skilled in the art. Advantages, features, and methods of achieving the present disclosure will become apparent by reference to the embodiments and accompanying drawings. This disclosure may, however, be embodied in many different forms and should not be limited to the example embodiments herein.

[0035] Hereinafter, embodiments of the present disclosure are described in more detail by referring to the attached drawings; in the drawings, like reference numerals denote like elements, and duplicative explanations thereof may not be provided. As used herein, the singular forms "a", "an", and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. Further, the use of "may" when describing embodiments of the inventive concept refers to "one or more embodiments of the inventive concept."

[0036] It will be further understood that the terms "comprises" and/or "comprising" used herein specify the presence of stated features or components, but do not preclude the presence or addition of one or more other features or components. Expressions such as "at least one of", "one of", "selected from", "at least one selected from", and "one

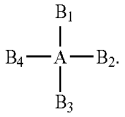
selected from", when preceding a list of elements, modify the entire list of elements and do not modify the individual elements of the list.

[0037] It will be understood that when a layer, region, or component is referred to as being "on" or "onto" another layer, region, or component, it may be directly or indirectly formed on the other layer, region, or component. That is, for example, intervening layers, regions, or components may be present.

[0038] Sizes of components in the drawings may be exaggerated for convenience of explanation. In other words, since sizes and thicknesses of components in the drawings are arbitrarily illustrated for convenience of explanation, the following embodiments of the present disclosure are not limited thereto.

[0039] A condensed cyclic compound according to an embodiment of the present disclosure is represented by Formula 1:

Formula 1

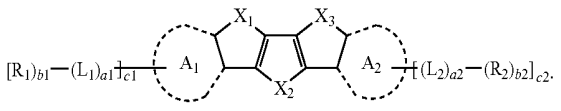


[0040] In Formula 1,

[0041] A may be a moiety represented by Formula 1-1, and

[0042] B_1 to B_4 may each independently be selected from a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted 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:

Formula 1-1



[0043] In Formula 1-1, X_1 may be a carbon atom (C) linked to B_1 and B_2 or a silicon atom (Si) linked to B_1 and B_2, X_2 may be a carbon atom linked to B_3 and B_4 or a silicon atom linked to B_3 and B_4, and X_3 may be O or S.

[0044] In some embodiments, for example, X_1 may be a carbon atom linked to B_1 and B_2, and X_2 may be a carbon atom linked to B_3 and B_4;

[0045] X_1 may be a carbon atom linked to B_1 and B_2, and X_2 may be a silicon atom linked to B_3 and B_4;

[0046] X_1 may be a silicon atom linked to B_1 and B_2, and X_2 may be a carbon atom linked to B_3 and B_4; or

[0047] X_1 may be a silicon atom linked to B_1 and B_2, and X_2 may be a silicon atom linked to B_3 and B_4.

[0048] In one or more embodiments, X_1 may be a carbon atom linked to B_1 and B_2, and X_2 may be a carbon atom linked to B_3 and B_4; or

[0049] X_1 may be a silicon atom linked to B_1 and B_2, and X_2 may be a silicon atom linked to B_3 and B_4.

[0050] In one or more embodiments, X_1 may be a carbon atom linked to B_1 and B_2, and X_2 may be a carbon atom linked to B_3 and B_4; or X_1 may be a silicon atom linked to B_1 and B_2, and X_2 may be a silicon atom linked to B_3 and B_4, and

[0051] B_1=B_2, B_3=B_4, or B_1=B_2=B_3=B_4.

[0052] In Formula 1-1, A_1 and A_2 may each independently be a benzene group, a pyridine group, a pyrimidine group, a pyridazine group, or a pyrazine group.

[0053] In one or more embodiments, A_1 and A_2 may each (e.g., both) be a benzene group.

[0054] In Formula 1-1, L_1 and L_2 may each independently be a substituted or unsubstituted C_5-C_{60} carbocyclic group, or a substituted or unsubstituted C_1-C_{60} heterocyclic group.

[0055] For example, L_1 and L_2 may each independently be selected from:

[0056] 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-fluorene group, a benzofluorene 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 pentaphenylene group, a hexacene group, a pyrrole group, an imidazole group, a pyrazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an isoindole group, an indole 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 carbazole group, a phenanthridine group, an acridine group, a phenanthroline group, a phenazine group, a benzoxazole group, a benzimidazole group, a furan group, a benzofuran group, a thiophene group, a benzothiophene group, a thiazole group, an isothiazole group, a benzothiazole group, an isoxazole group, an oxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a benzoxazole group, a dibenzofuran group, a dibenzothiophene group, a benzocarbazole group, and a dibenzocarbazole group; and

[0057] 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-fluorene group, a benzofluorene 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 pentaphenylene group, a hexacene group, a pyrrole group, an imidazole group, a pyrazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an isoindole group, an indole 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 carbazole group, a phenanthridine group, an acridine group, a phenanthroline group, a phenazine group, a benzoxazole group, a benzimidazole group, a furan group, a benzofuran group, a thiophene group, a benzothiophene group, a thiazole group,

an isothiazole group, a benzothiazole group, an isoxazole group, an oxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a benzoxazole group, a dibenzofuran group, a dibenzothiophene group, a benzocarbazole group, and a dibenzocarbazole group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a C_6-C_{20} aryl group, a C_2-C_{20} heteroaryl group and $—Si(Q_{31})(Q_{32})(Q_{33})$ (where 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),

[0058] but embodiments of the present disclosure are not limited thereto.

[0059] In Formula 1-1, a1 and a2 may each independently be an integer of 0 to 5. a1 indicates the number of L_1, and when a1 is two or more, the two or more L_1(s) may be identical to or different from each other, and when a1 is 0, $*—(L_1)_{a1}—*'$ may be a single bond. a2 may be the same as described in connection with a1.

[0060] In one or more embodiments, a1 and a2 may each independently be 0 or 1.

[0061] In Formula 1-1, R_1 and R_2 may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_2-C_{60} alkynyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, $—Si(Q_1)(Q_2)(Q_3)$, $—B(Q_1)(Q_2)$, $—C(=O)(Q_1)$, $—N(Q_1)(Q_2)$, $—P(=O)(Q_1)(Q_2)$, $—P(=O)_2(Q_1)$, $—P(=S)(Q_1)(Q_2)$, $—P(=S)_2(Q_1)$, $—S(=O)(Q_1)(Q_2)$, and $—S(=O)_2(Q_1)(Q_2)$, where Q_1 to Q_3 may each independently be the same as described herein in connection with Q_{31} to Q_{33}.

[0062] In some embodiments, for example, R_1 and R_2 may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a methyl group, an ethyl group, a propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an isoamyl group, a hexyl group, a phenyl group, a biphenyl group, and a pyridinyl group. In some embodiments, R_1 and R_2 may each be hydrogen, but embodiments of the present disclosure are not limited thereto.

[0063] In Formula 1-1, b1 and b2 may each independently be an integer from 1 to 10. b1 indicates the number of R_1(s), wherein, when b1 is two or more, the two or more R_1(s) may be identical to or different from each other. b2 may be the same as described in connection with b1.

[0064] In Formula 1-1, c1 and c2 may each independently be 1, 2, 3, or 4. c1 indicates the number of substituents represented by $*—[(L_1)_{a1}—(R_1)_{b1}]$, wherein, when c1 is two or more, the two or more $*—[(L_1)_{a1}—(R_1)_{b1}]$(s) may be identical to or different from each other. c2 may be the same as described in connection with c1.

[0065] In Formula 1, B_1 to B_4 may each indicate a ligand linked to A.

[0066] In one or more embodiments, B_1 to B_4 may each independently be selected from a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted 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.

[0067] In one or more embodiments, B_1 to B_4 in Formula 1 may each independently be selected from:

[0068] a phenyl group and a pyridinyl group; and

[0069] a phenyl group and a pyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a methyl group, an ethyl group, a propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an isoamyl group, a hexyl group, a phenyl group, and $—Si(Q_{31})(Q_{32})(Q_{32})$.

[0070] In one or more embodiments, B_1 to B_4 in Formula 1 may each independently be selected from:

[0071] a phenyl group and a pyridinyl group; and

[0072] a phenyl group and a pyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a methyl group, an ethyl group, a propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an isoamyl group, a hexyl group, a phenyl group, and $—Si(Q_{31})(Q_{32})(Q_{32})$, and

[0073] R_1 and R_2 in Formula 1-1 may each be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a methyl group, an ethyl group, a propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an isoamyl group, a hexyl group, a phenyl group, a biphenyl group, and a pyridinyl group.

[0074] In one or more embodiments, B_1 to B_4 in Formula 1 may each independently be selected from:

[0075] a phenyl group and a pyridinyl group; and

[0076] a phenyl group and a pyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a methyl group, an ethyl group, a propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an isoamyl group, a hexyl group, a phenyl group and $—S(Q_{31})(Q_{32})(Q_{32})$, and

[0077] A_1 and A_2 in Formula 1-1 may each be a benzene group.

[0078] In one or more embodiments, B_1 to B_4 in Formula 1 may each independently be selected from:

[0079] a phenyl group and a pyridinyl group; and

[0080] a phenyl group and a pyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a methyl group, an ethyl group, a propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a phenyl group, and —$Si(Q_{31})(Q_{32})(Q_{32})$, and

[0081] A_1 and A_2 in Formula 1-1 may each be a benzene group, a1 and a2 may each be 0, and R_1 and R_2 may each be hydrogen.

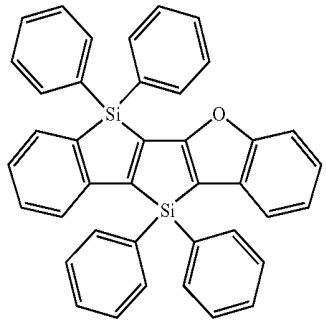
[0082] In one or more embodiments, in Formula 1, B_1=B_2, B_3=B_4, or B_1=B_2=B_3=B_4.

[0083] In one or more embodiments, in Formula 1, the dihedral angle between a plane P1 including A (e.g., the fused ring core of A) and a plane P2 including B_n (e.g., a plane including B_1, B_2, and X_1, or a plane including B_3, B_4, and X_2) may be 60° or more. n may be 1, 2, 3, or 4.

[0084] As described above, when a dihedral angle between a core represented by A and a ligand represented by B_n is 60° or more, a conjugate structure of the core and the ligand may be broken (e.g., electronic conjugation or coupling between the core and ligand may be reduced or substantially eliminated). As a result, a change in triplet energy of the ligand may be minimized or reduced, and the triplet energy of the ligand may be more than twice the triplet energy of the core. Therefore, the condensed cyclic compound may exhibit excellent delayed fluorescence characteristics. In some embodiments, intermolecular interaction may be reduced or disfavored, thereby preventing or reducing the formation of an excimer. As such, the characteristic light-emission spectrum of a material may be maintained, and blue light may be emitted.

[0085] In one or more embodiments, the condensed cyclic compound represented by Formula 1 may be selected from Compounds 1 to 4, but embodiments of the present disclosure are not limited thereto:

1



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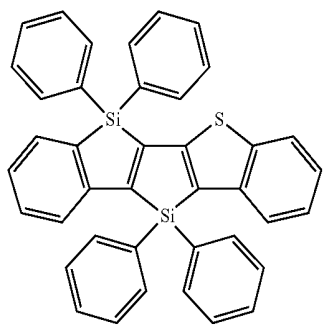

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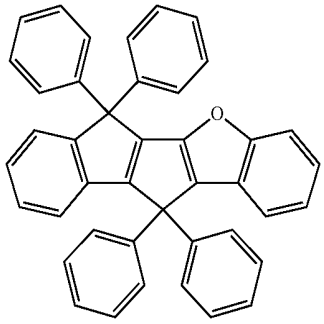
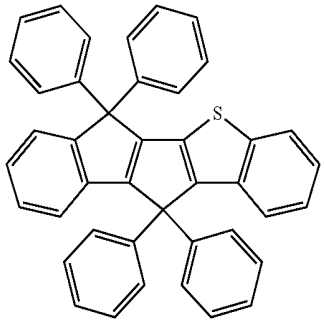
3



4



[0086] The compound represented by Formula 1 may satisfy the condition of Equation 1:

$$E_{S1}<2E_{T1}<E_{T2}. \quad \text{Equation 1}$$

[0087] In Equation 1,

[0088] E_{S1} is the first singlet energy level of the condensed cyclic compound,

[0089] E_{T1} is the first triplet energy level of the condensed cyclic compound, and

[0090] E_{T2} is the second triplet energy level of the condensed cyclic compound.

[0091] E_{S1}, E_{T1}, and E_{T2} may be evaluated or calculated using DFT methods, for example, using Gaussian (Gaussian, Inc., Wallingford, Conn.) on structurally optimized molecules using a B3LYP/6-31G*(d,p) functional and basis set.

[0092] When the condensed cyclic compound represented by Formula 1 satisfies Equation 1, an energy transition to a second triplet state should not occur (e.g., may be disfavored) during up-conversion of the condensed cyclic compound from a triplet state to a singlet state through interaction with an adjacent molecule in a triplet energy state. Thus, energy loss may not occur or may be reduced. Therefore, when the condensed cyclic compound satisfies Equation 1, all molecules in an excited triplet state may transition to singlet states, and the emission layer including the condensed cyclic compound may emit high-efficiency delayed fluorescence.

[0093] In some embodiments, the compound represented by Formula 1 may have a singlet conversion efficiency of about 40% to about 62.5%, and the singlet conversion efficiency may be evaluated using a transient EL apparatus.

[0094] For example, in Equation 1, E_{S1} may be about 2.7 eV to about 3.0 eV. When E_{S1} is within this range, an organic light-emitting device including the condensed cyclic compound may emit blue light. For example, an organic light-emitting device including the condensed cyclic compound may emit blue fluorescence.

[0095] In some embodiments, in Equation 1, E_{T1} may be about 1.4 eV to about 1.7 eV.

[0096] In some embodiments, in Equation 1, E_{T2} may be about 2.8 eV to about 3.4 eV.

[0097] In some embodiments, the compound represented by Formula 1 may satisfy Equation 2:

$$2E_{AT1}<E_{BT1}. \quad \text{Equation 2}$$

[0098] In Equation 2,

[0099] E_{AT1} is the first (e.g., lowest energy) triplet energy level of A, and

[0100] E_{BT1} is first (e.g., lowest energy) triplet energy level of B_n.

[0101] n is 1, 2, 3, or 4.

[0102] For example, in Equation 2, the first triplet energy level (E_{BT1}) of B_n may be about 3.01 eV to about 3.21 eV.

[0103] When the condensed cyclic compound represented by Formula 1 satisfies Equation 2, energy may not be transferred to the ligand (e.g., from the core to the ligand), and energy conversion may occur only in the core. Thus, energy loss may be minimized or reduced.

[0104] Another aspect of embodiments of the present disclosure provides 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, wherein the organic layer includes an emission layer and at least one of the condensed cyclic compound described above.

[0105] The expression "(an organic layer) includes at least one condensed cyclic compound" as used herein may include a case in which "(an organic layer) includes identical compounds represented by Formula 1" as well as a case in which "(an organic layer) includes two or more different condensed cyclic compounds."

[0106] For example, the organic layer may include, as the condensed cyclic compound, only Compound 1. In this regard, Compound 1 may exist in an emission layer of the organic light-emitting device. In one or more embodiments, the organic layer may include, as the condensed cyclic compound, Compound 1 and Compound 2. In this regard, Compound 1 and Compound 2 may exist in the same layer (for example, Compound 1 and Compound 2 may both exist in an emission layer), or in different layers (for example, Compound 1 may exist in an emission layer and Compound 2 may exist in an electron transport layer).

[0107] In one or more embodiments, the first electrode may be an anode, and the second electrode may be a cathode, and the organic layer may further include a hole transport region between the first electrode and the emission layer and an electron transport region between the emission layer and the second electrode, and the hole transport region may include 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 may include a buffer layer, a hole blocking layer, an electron control layer, an electron transport layer, an electron injection layer, or any combination thereof.

[0108] In one or more embodiments, the emission layer may include the condensed cyclic compound.

[0109] For example, the emission layer may further include a host, and an amount of the host in the emission layer may be greater than that of the condensed cyclic compound. In some embodiments, the condensed cyclic compound may be a delayed fluorescence emitter.

[0110] For example, an amount of the condensed cyclic compound in the emission layer may be about 0.01 parts by weight to about 30 parts by weight based on 100 parts by weight of the host, but embodiments of the present disclosure are not limited thereto.

[0111] In some embodiments, the host may include a compound represented by Formula 301:

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

[0112] In Formula 301,

[0113] 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,

[0114] xb11 may be 1, 2, or 3,

[0115] L_{301} may be selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3-C_{10} cycloalkenylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6-C_{60} arylene group, a substituted or unsubstituted C_1-C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group;

[0116] xb1 may be an integer from 0 to 5,

[0117] 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 —$P(=O)(Q_{301})(Q_{302})$,

[0118] xb21 may be an integer from 1 to 5, and

[0119] Q_{301} to Q_{303} may each independently be selected from 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, the emission layer may include the condensed cyclic compound, and may emit blue light from the emission layer, the blue light having a maximum emission wavelength of about 420 nm to about 470 nm.

[0121] The term "organic layer" as used herein may refer to a single layer and/or a plurality of layers between the first electrode and the second electrode of the organic light-emitting device. The material included in the "organic layer" is not limited to being an organic material.

Description of FIG. **1**

[0122] FIG. **1** is a schematic view of an organic light-emitting device **10** according to an embodiment of the

present disclosure. The organic light-emitting device **10** includes a first electrode **110**, an organic layer **150**, and a second electrode **190**.

[0123] Hereinafter, the structure of the organic light-emitting device **10** according to an embodiment of the present disclosure and a method of manufacturing the organic light-emitting device **10** will be described in connection with FIG. **1**.

First Electrode **110**

[0124] In FIG. **1**, a substrate may be additionally provided under the first electrode **110** and/or above the second electrode **190**. The substrate may be a glass substrate and/or a plastic substrate, each having excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and/or water resistance.

[0125] The first electrode **110** may be formed by depositing or sputtering a material for forming the first electrode **110** on the substrate. When the first electrode **110** is an anode, the material for forming a first electrode may be selected from materials with a high work function to facilitate hole injection.

[0126] The first electrode **110** may be a reflective electrode, a semi-transmissive electrode, or a transmissive electrode. When the first electrode **110** is a transmissive electrode, the material for forming a first electrode may be selected from indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO_2), zinc oxide (ZnO), and any combination thereof, but embodiments of the present disclosure are not limited thereto. When the first electrode **110** is a semi-transmissive electrode or a reflective electrode, the material for forming the first electrode **110** may be selected from magnesium (Mg), silver (Ag), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), magnesium-silver (Mg—Ag), and any combination thereof. However, embodiments of the material for forming the first electrode **110** are not limited thereto.

[0127] The first electrode **110** may have a single-layered structure, or a multi-layered structure including two or more layers. For example, the first electrode **110** may have a three-layered structure of ITO/Ag/ITO, but embodiments of the structure of the first electrode **110** are not limited thereto.

Organic Layer **150**

[0128] The organic layer **150** is on the first electrode **110**. The organic layer **150** may include an emission layer.

[0129] The organic layer **150** may further include a hole transport region between the first electrode **110** and the emission layer, and/or an electron transport region between the emission layer and the second electrode **190**.

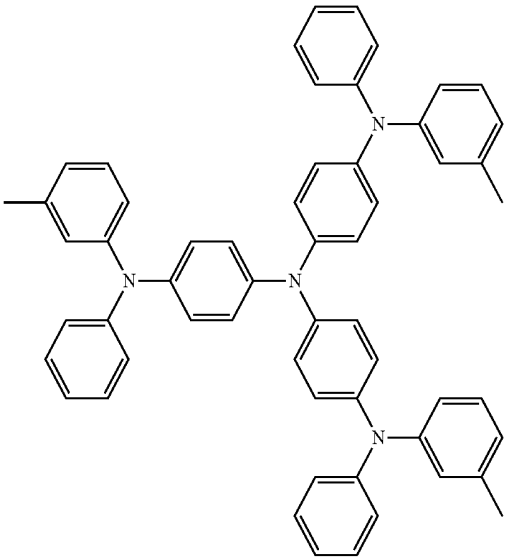
[Hole Transport Region in Organic Layer **150**]

[0130] The hole transport region may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

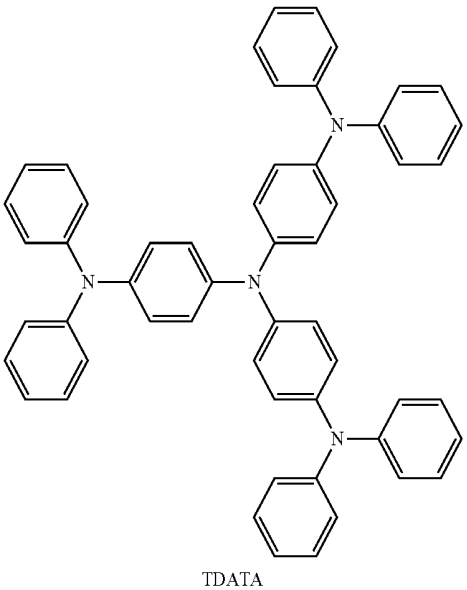
[0131] The hole transport region may include at least one layer selected from a hole injection layer, a hole transport layer, an emission auxiliary layer, and an electron blocking layer.

[0132] For example, the hole transport region may have a single-layered structure including a single layer including a plurality of different materials, or a multi-layered structure having a hole injection layer/hole transport layer structure, a hole injection layer/hole transport layer/emission auxiliary layer structure, a hole injection layer/emission auxiliary layer structure, a hole transport layer/emission auxiliary layer structure, or a hole injection layer/hole transport layer/electron blocking layer structure, wherein the constituting layers of each structure are sequentially stacked from the first electrode 110 in this stated order, but the structure of the hole transport region is not limited thereto.

[0133] The hole transport region may include at least one selected from m-MTDATA, TDATA, 2-TNATA, NPB (NPD), 8-NPB, TPD, Spiro-TPD, Spiro-NPB, methylated-NPB, TAPC, HMTPD, 4,4',4"-tris(N-carbazolyl)triphenylamine (TCTA), polyaniline/dodecylbenzenesulfonic acid (PANI/DBSA), PEDOT/PSS (poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate)), polyaniline/camphor sulfonic acid (PANI/CSA), polyaniline/poly(4-styrenesulfonate) (PANI/PSS), a compound represented by Formula 201, and a compound represented by Formula 202:



m-MTDATA



TDATA

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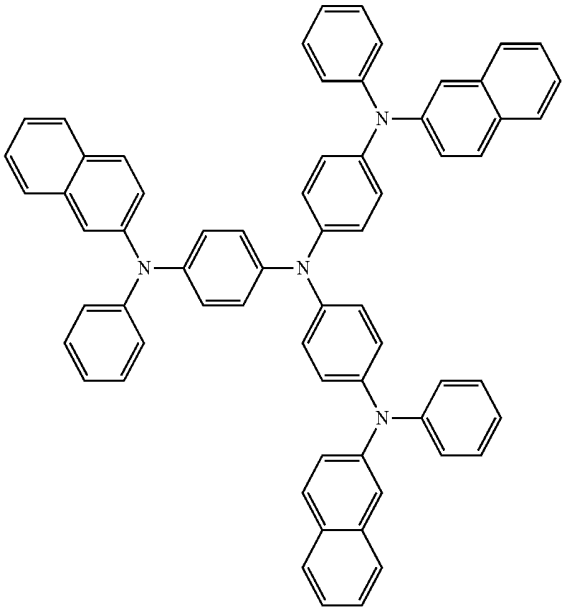
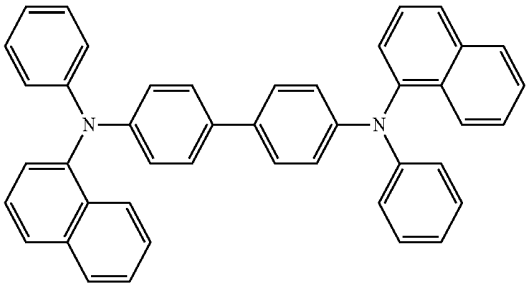
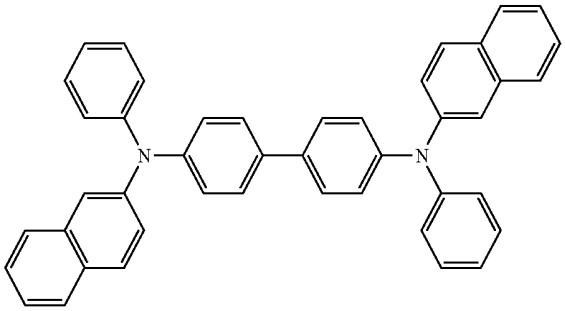


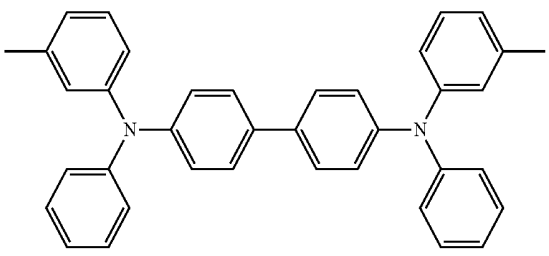
2-TNATA



NPB



β-NPB



TPD

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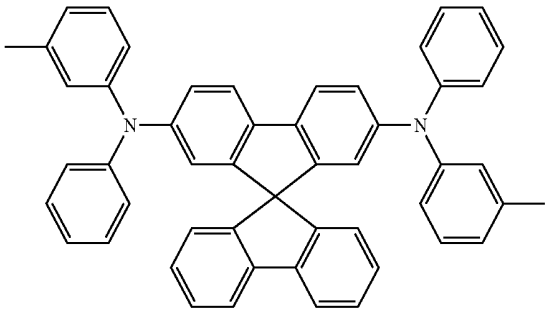
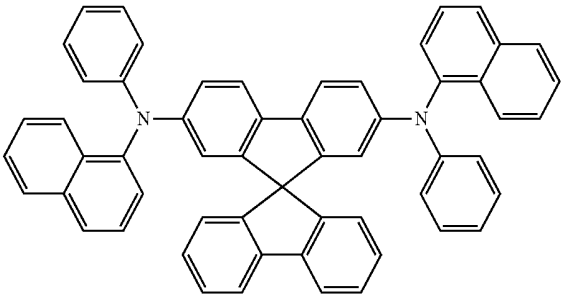
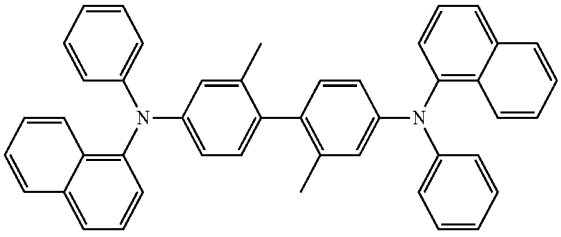


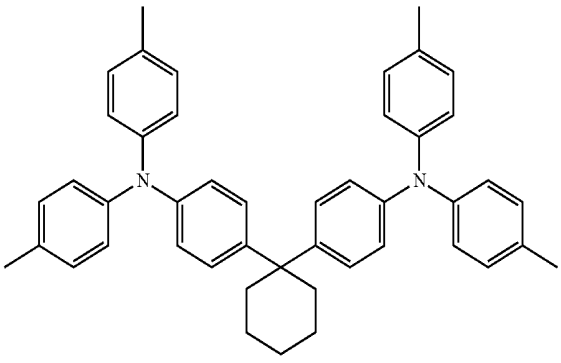
Spiro-TPD



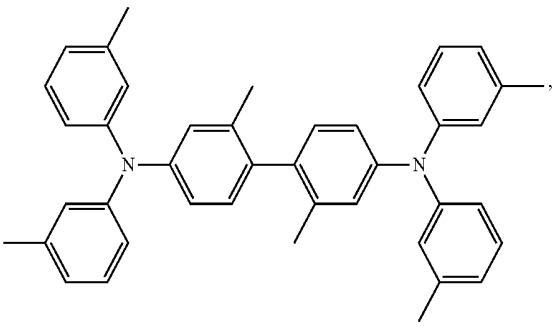
Spiro-NPB



methylated NPB



TAPC



HMTPD

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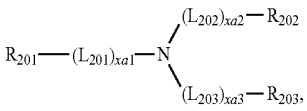
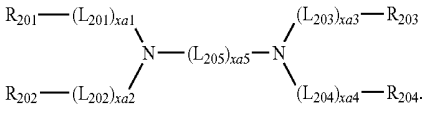
Formula 201



Formula 202



[0134] In Formulae 201 and 202,

[0135] 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,

[0136] 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,

[0137] xa1 to xa4 may each independently be an integer of 0 to 3,

[0138] xa5 may be an integer of 1 to 10, and

[0139] 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.

[0140] 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.

[0141] In one or more embodiments, regarding Formulae 201 and 202,

[0142] L_{201} to L_{205} may each independently be selected from:

[0143] 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; and

[0144] 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

[0145] 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.

[0146] In one or more embodiments, xa1 to xa4 may each independently be 0, 1, or 2.

[0147] In one or more embodiments, xa5 may be 1, 2, 3, or 4.

[0148] In one or more embodiments, R_{201} to R_{204} and Q_{201} may each independently be selected from a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group; and

[0149] 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

[0150] Q_{31} to Q_{33} may each independently be the same as described above.

[0151] In one or more embodiments, in Formula 201, at least one selected from R_{201} to R_{203} may each independently be selected from:

[0152] a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

[0153] 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,

[0154] but embodiments of the present disclosure are not limited thereto.

[0155] 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.

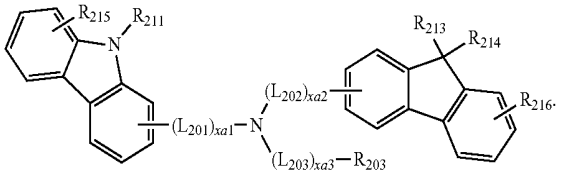
[0156] In one or more embodiments, in Formula 202, at least one selected from R_{201} to R_{204} may be selected from:

[0157] a carbazolyl group; and

[0158] a carbazolyl group substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1-C_{10} alkyl group, a phenyl group substituted with —F, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, but embodiments of the present disclosure are not limited thereto.

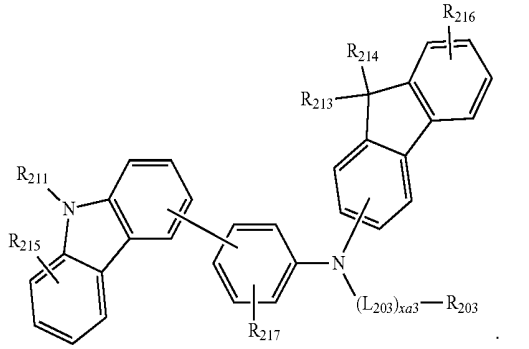
[0159] The compound represented by Formula 201 may be represented by Formula 201A:

Formula 201A



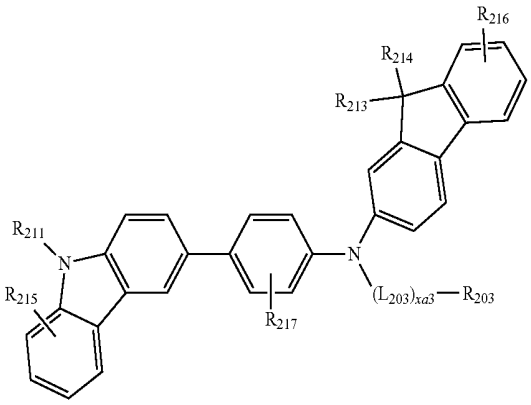
[0160] In one or more embodiments, the compound represented by Formula 201 may be further represented by Formula 201A(1), but embodiments of the present disclosure are not limited thereto:

Formula 201A(1)



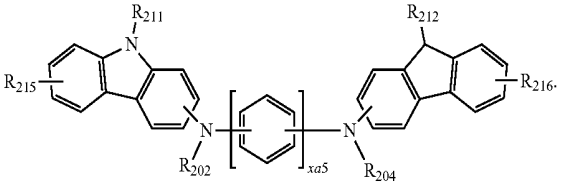
[0161] In one or more embodiments, the compound represented by Formula 201 may be further represented by Formula 201A-1, but embodiments of the present disclosure are not limited thereto:

Formula 201A-1



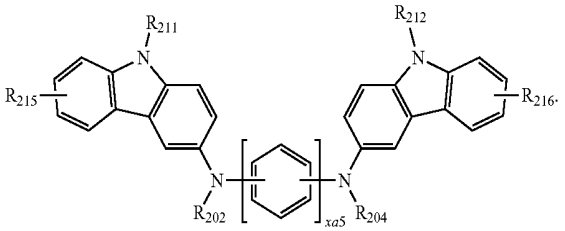
[0162] In one or more embodiments, the compound represented by Formula 202 may be further represented by Formula 202A:

Formula 202A



[0163] In one or more embodiments, the compound represented by Formula 202 may be further represented by Formula 202A-1:

Formula 202A-1



In Formulae 201A, 201A(1), 201A-1, 202A, and 202A-1,

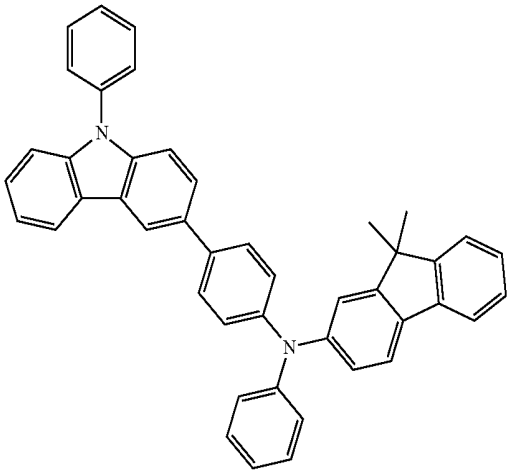
[0164] L_{201} to L_{203}, xa1 to xa3, xa5, and R_{202} to R_{204} may each independently be the same as described above,

[0165] R_{211} and R_{212} may be understood by referring to the description provided herein in connection with R_{203}, and

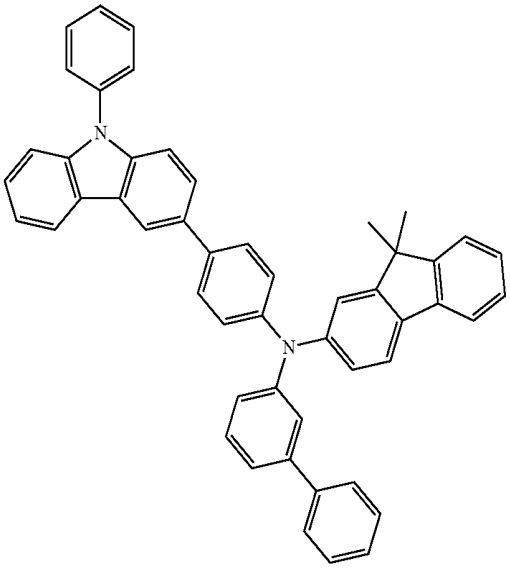
[0166] R_{213} to R_{217} may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, 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.

[0167] The hole transport region may include at least one compound selected from Compounds HT1 to HT39, but embodiments of the present disclosure are not limited thereto:

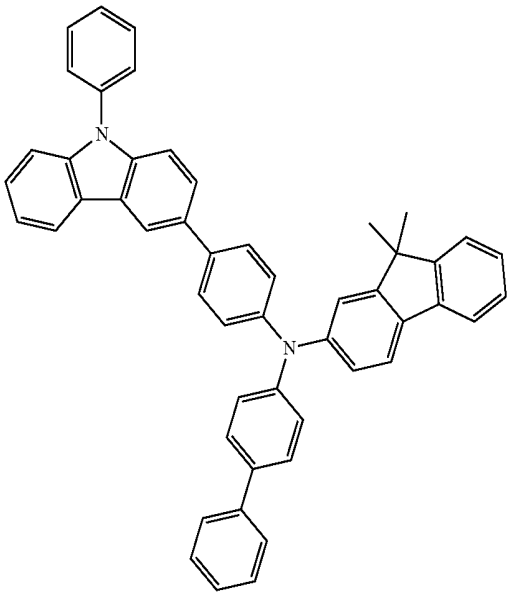
HT1



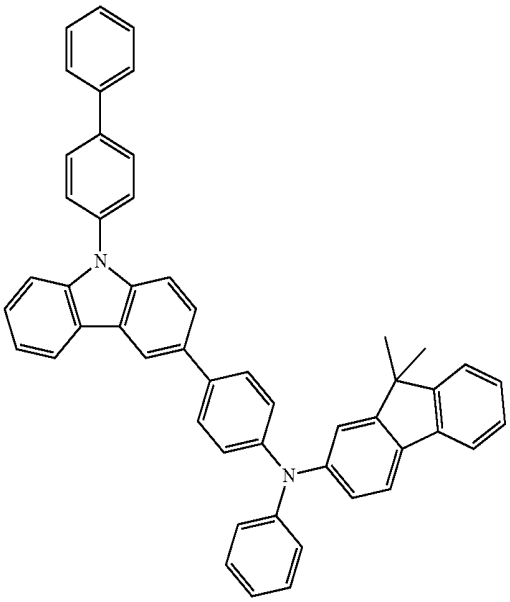
HT2



HT3



HT4



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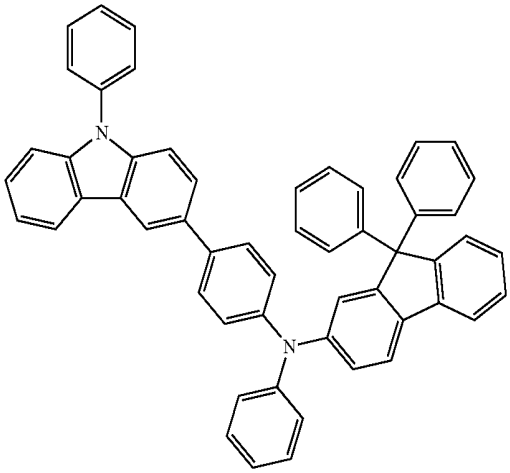
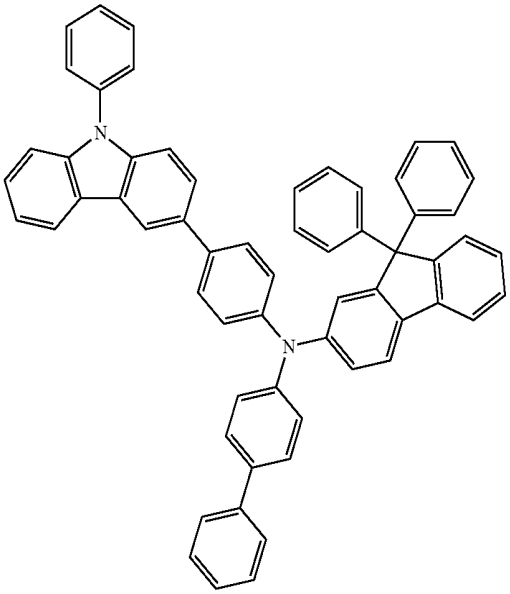
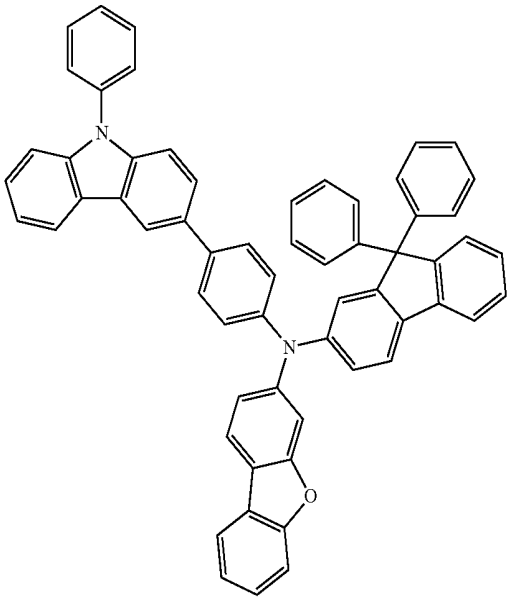
HT5



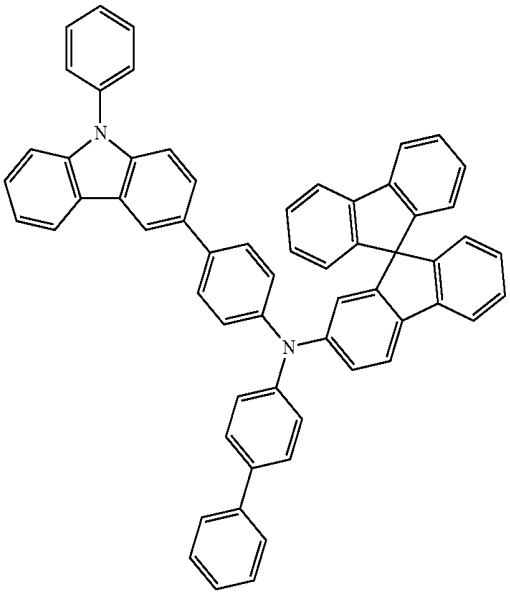
HT6



HT7



HT8



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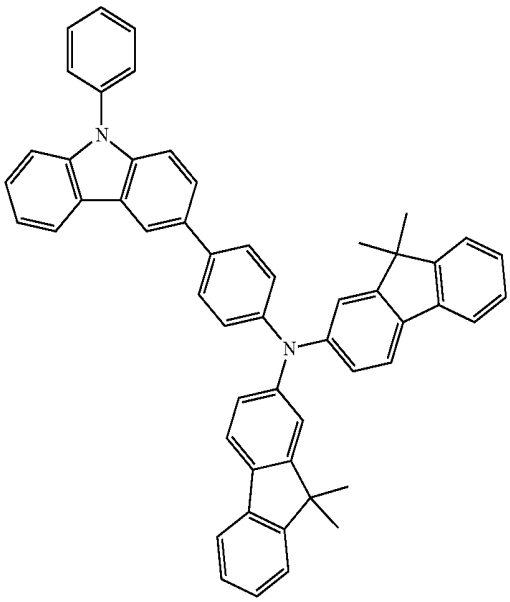
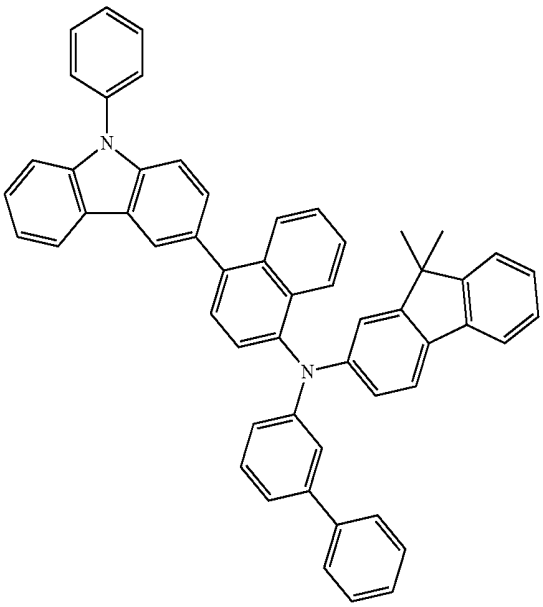
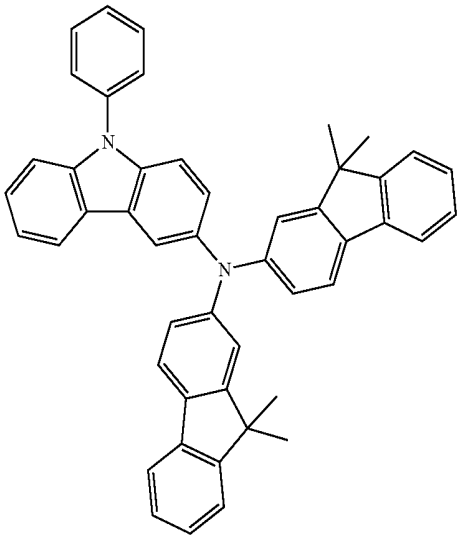
HT9



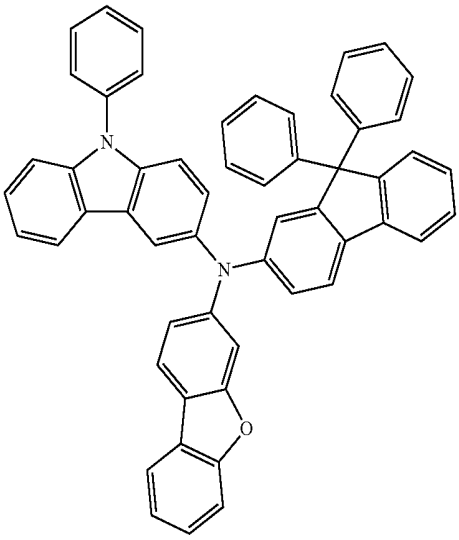
HT10



HT11



HT12



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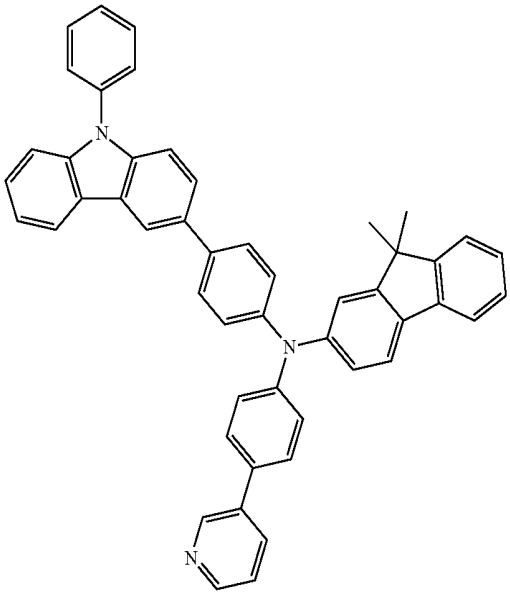
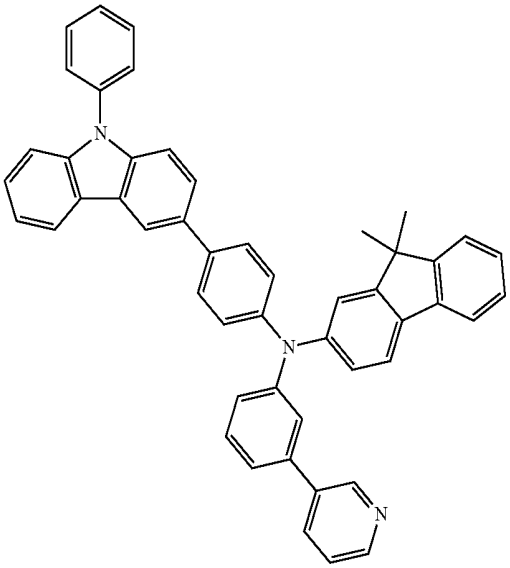
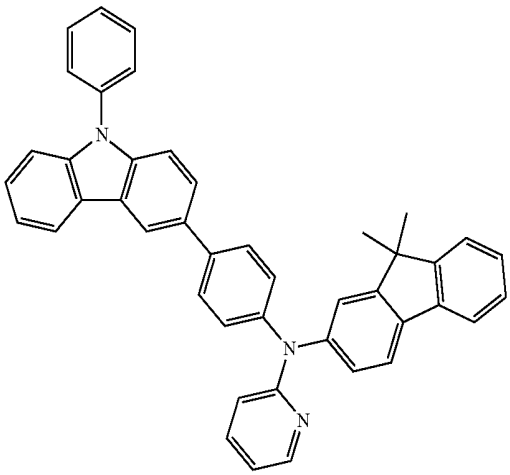
HT13



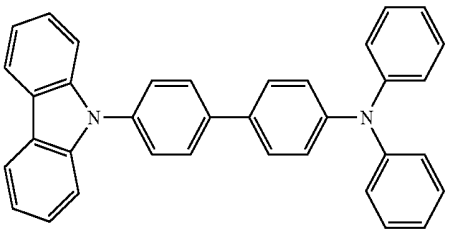
HT14



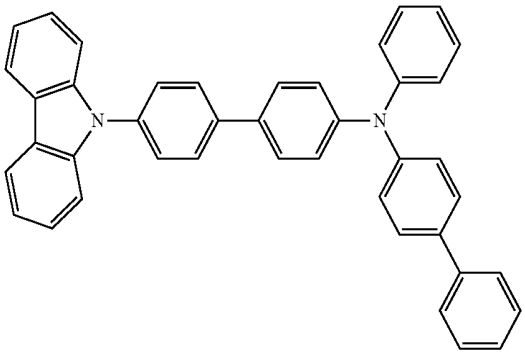
HT15



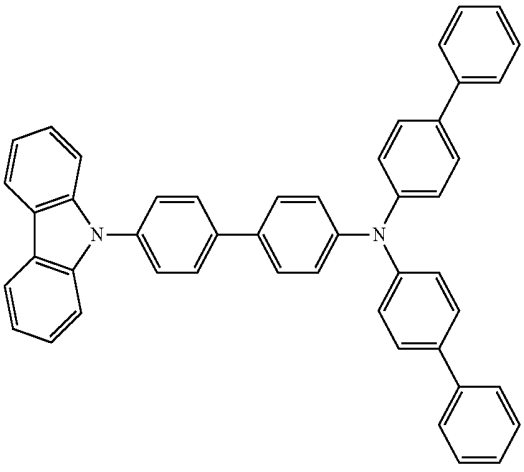
HT16



HT17



HT18



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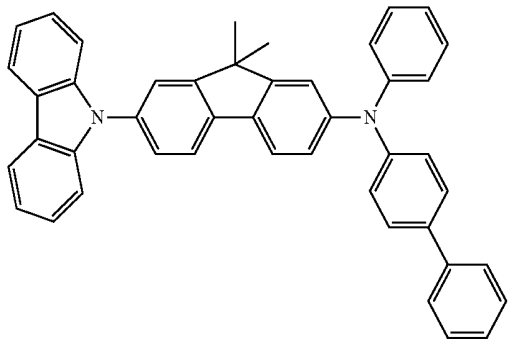
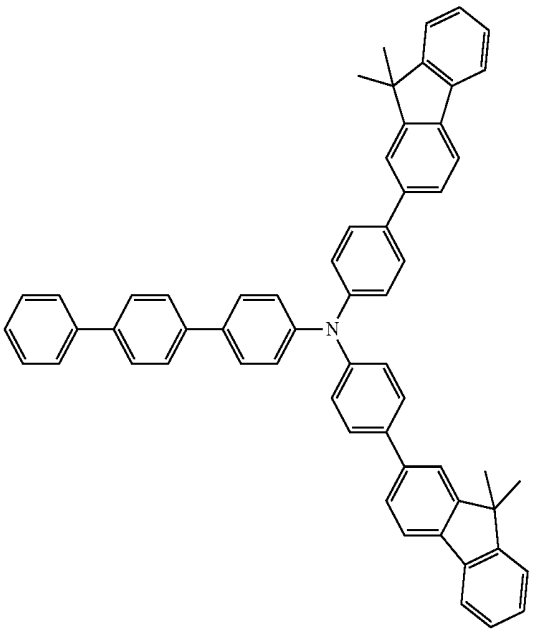
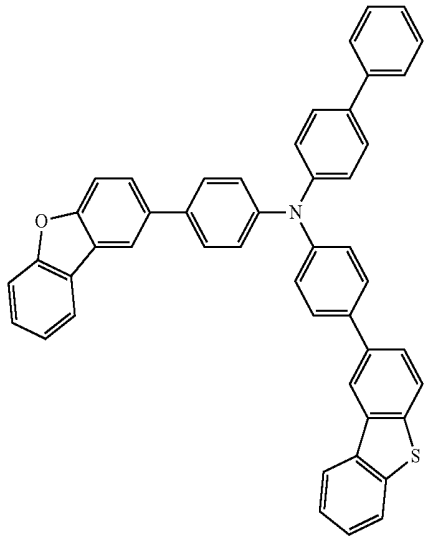
HT19



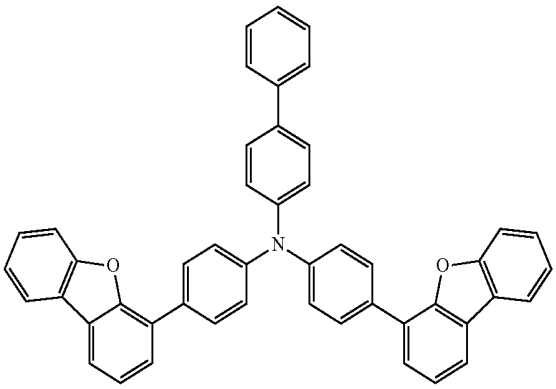
HT20



HT21



HT22



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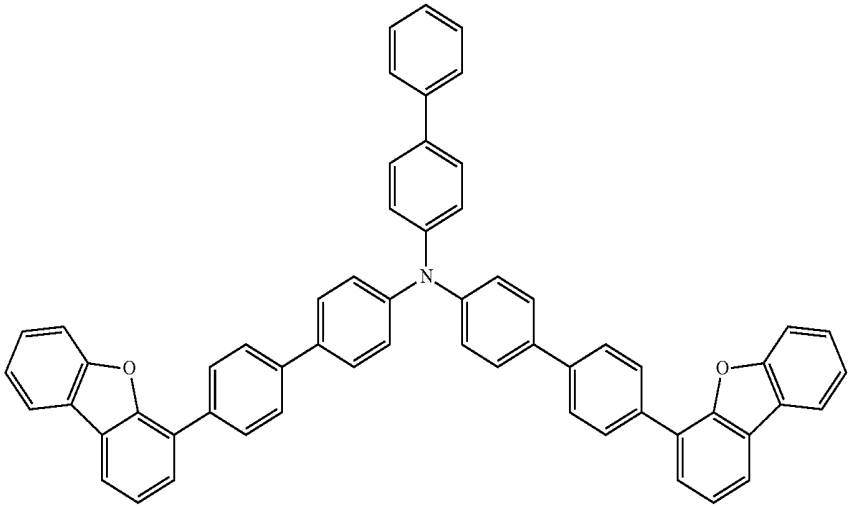
HT23



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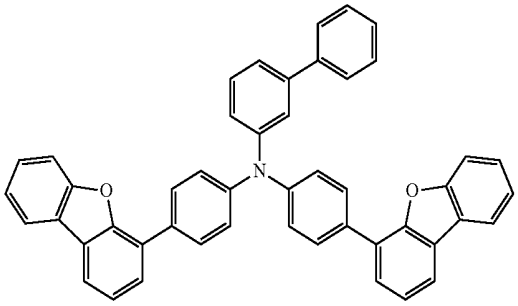

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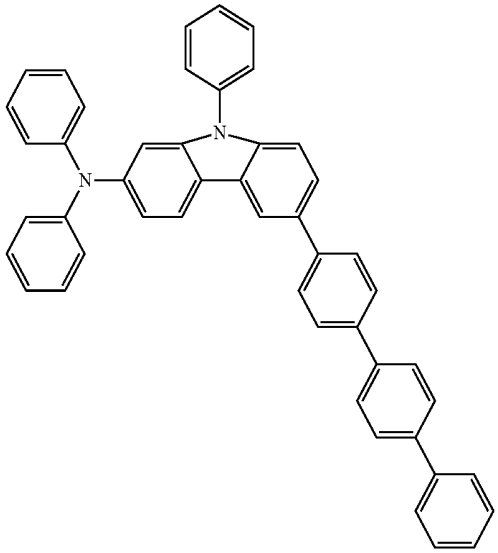

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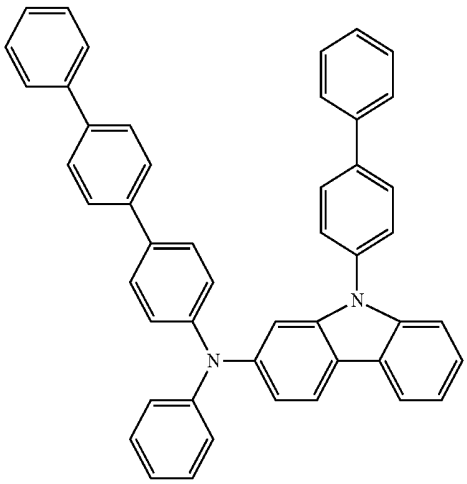

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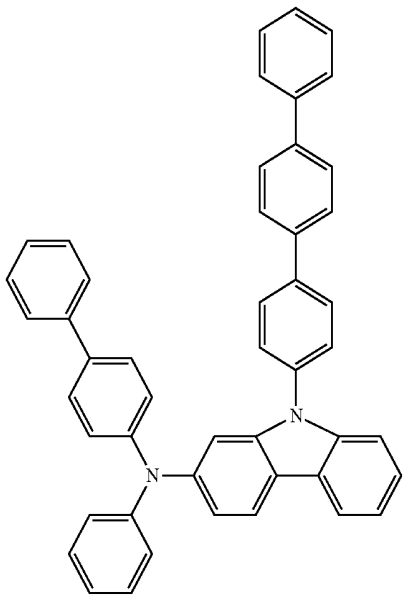

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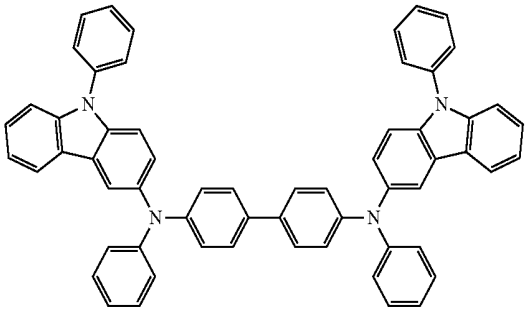

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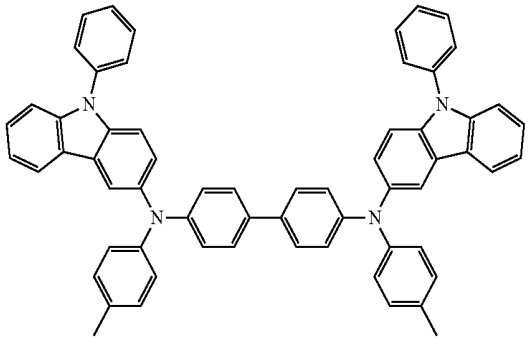

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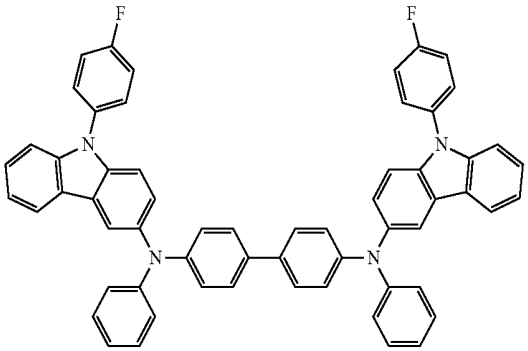

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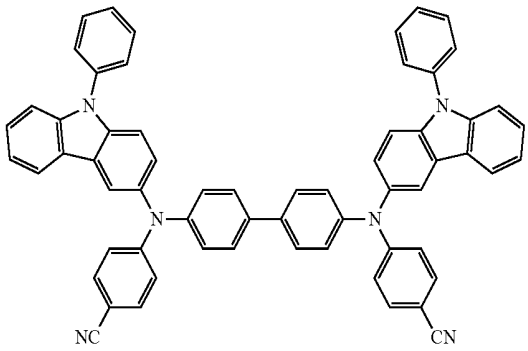

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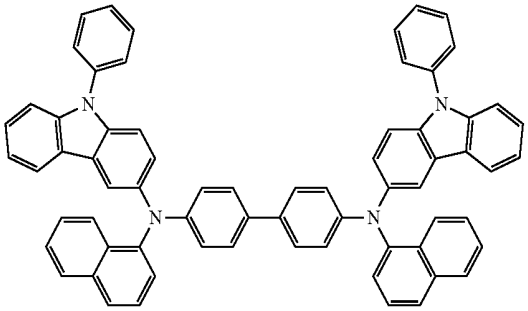

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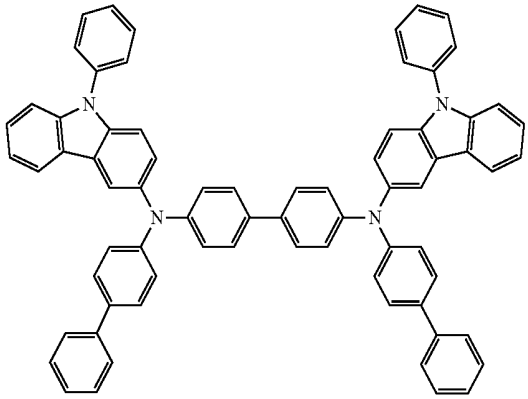

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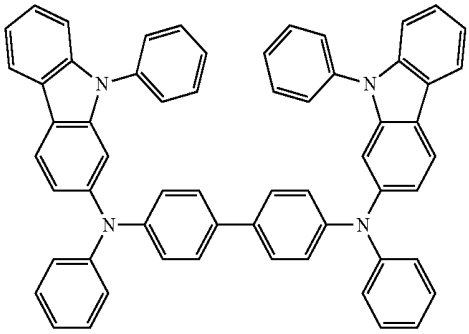

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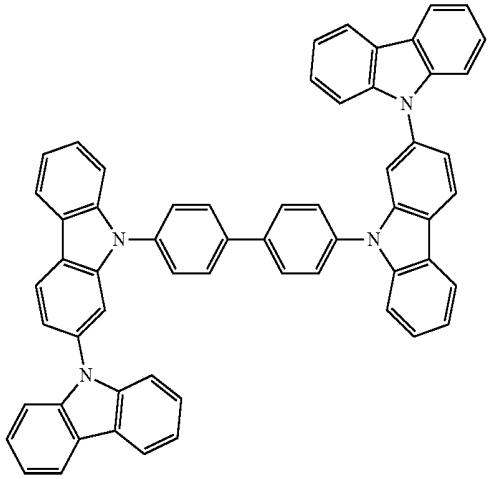

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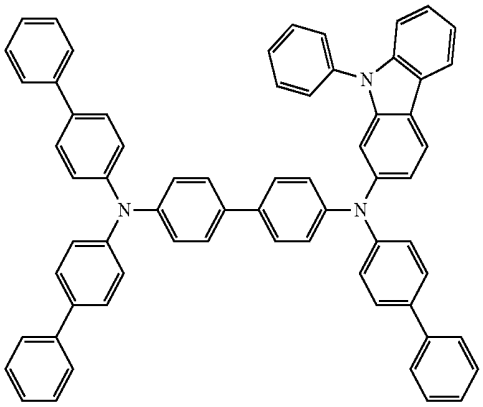

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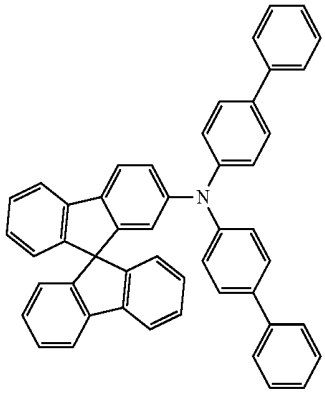
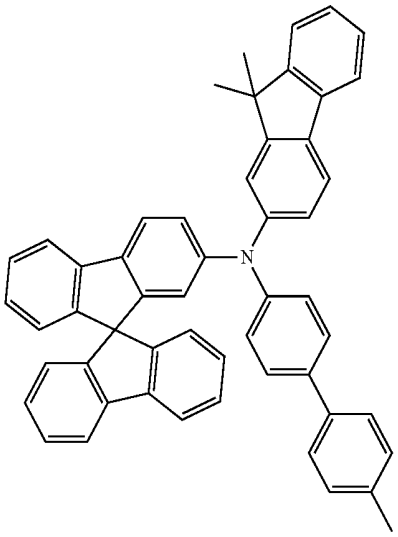


HT38



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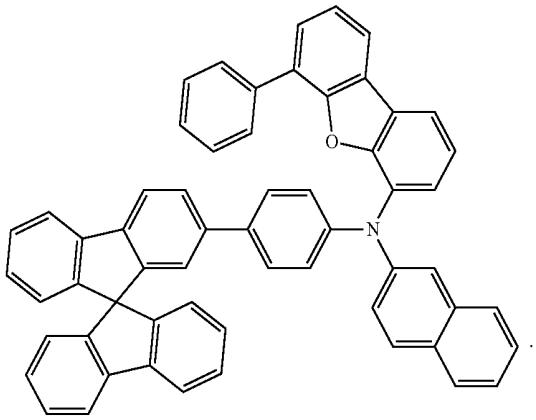


[0168] The thickness of the hole transport region may be about 100 Å to about 10,000 Å, for example, about 100 Å to about 1,000 Å. When the hole transport region includes at least one of a hole injection layer and a hole transport layer, the thickness of the hole injection layer may be about 100 Å to 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 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, the hole injection layer, and the hole transport layer are each within these ranges, excellent hole transporting characteristics may be obtained without a substantial increase in driving voltage.

[0169] 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 (e.g., by adjusting the optical resonance distance in the device to match the wavelength of light emitted from the emission layer), and the electron blocking layer may block or reduce the flow of electrons from an electron transport region. The emission auxiliary layer and the electron blocking layer may each independently include the materials described above.

[P-Dopant]

[0170] The hole transport region may further include, in addition to these materials, a charge-generation material for the improvement of conductive properties. The charge-generation material may be homogeneously or non-homogeneously dispersed in the hole transport region.

[0171] The charge-generation material may be, for example, a p-dopant.

[0172] In one or more embodiments, the p-dopant may have a lowest unoccupied molecular orbital (LUMO) energy level of −3.5 eV or less.

[0173] The p-dopant may include at least one selected from a quinone derivative, a metal oxide, and a cyano group-containing compound, but embodiments of the present disclosure are not limited thereto.

[0174] For example, the p-dopant may include at least one selected from:

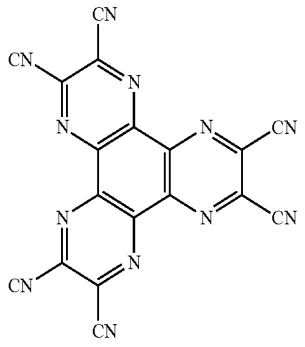
[0175] a quinone derivative (such as tetracyanoquinodimethane (TCNQ) and/or 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F4-TCNQ));

[0176] a metal oxide (such as tungsten oxide and/or molybdenum oxide);

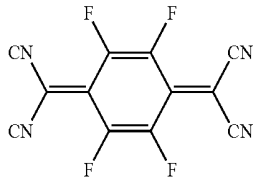
[0177] 1,4,5,8,9,11-hexaazatriphenylene-hexacarbonitrile (HAT-CN); and

[0178] a compound represented by Formula 221,

[0179] but embodiments of the present disclosure are not limited thereto:

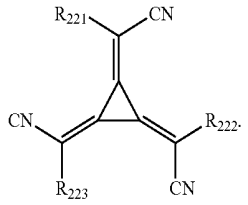


HAT-CN



F4-TCNQ

Formula 221



[0180] In Formula 221,

[0181] R_{221} to R_{223} may each independently be selected from a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, wherein at least one selected from R_{221} to R_{223} may have at least one substituent selected from a cyano group, —F, —Cl, —Br, —I, a C_1-C_{20} alkyl group substituted with —F, a C_1-C_{20} alkyl group substituted with —Cl, a C_1-C_{20} alkyl group substituted with —Br, and a C_1-C_{20} alkyl group substituted with —I.

Emission Layer in Organic Layer **150**

[0182] When the organic light-emitting device **10** is a full-color organic light-emitting device, the emission layer may be patterned into a red emission layer, a green emission layer, or a blue emission layer, according to a sub-pixel (e.g., corresponding to a group of sub-pixels). In one or more embodiments, the emission layer may have a stacked structure including 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 may contact each other or may be separated from each other. In one or more embodiments, the emission layer may include two or more materials selected from a red light-emitting material, a green light-emitting material, and a blue light-emitting material, in which the two or more materials are mixed with each other in a single layer to emit white light.

[0183] The emission layer may include a host and a dopant. The dopant may include at least one selected from a phosphorescent dopant and a fluorescent dopant.

[0184] An amount of the dopant in the emission layer may be about 0.01 parts by weight to about 30 parts by weight based on 100 parts by weight of the host, but embodiments of the present disclosure are not limited thereto.

[0185] The thickness of the emission layer may be about 100 Å to about 1,000 Å, for example, about 200 Å to about 600 Å. When the thickness of the emission layer is within this range, excellent light-emission characteristics may be obtained without a substantial increase in driving voltage.

[Host in Emission Layer]

[0186] In one or more embodiments, the host may include a compound represented by Formula 301.

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

[0187] In Formula 301,

[0188] 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,

[0189] xb11 may be 1, 2, or 3,

[0190] L_{301} may each independently be selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3-C_{10} cycloalkenylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6-C_{60} arylene group, a substituted or unsubstituted C_1-C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group;

[0191] xb1 may be an integer from 0 to 5,

[0192] 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 $—P(=O)(Q_{301})(Q_{302})$,

[0193] xb21 may be an integer from 1 to 5, and

[0194] 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, but embodiments of the present disclosure are not limited thereto.

[0195] In one or more embodiments, Ar_{301} in Formula 301 may be selected from:

[0196] a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, and a dibenzothiophene group; and

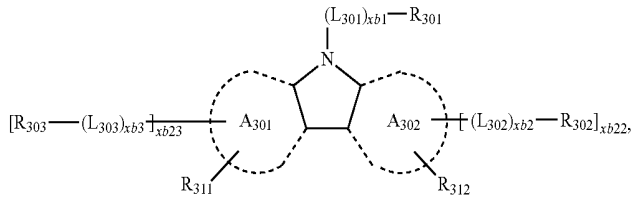
[0197] a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, and a dibenzothiophene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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

[0198] 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. However, embodiments of the present disclosure are not limited thereto.

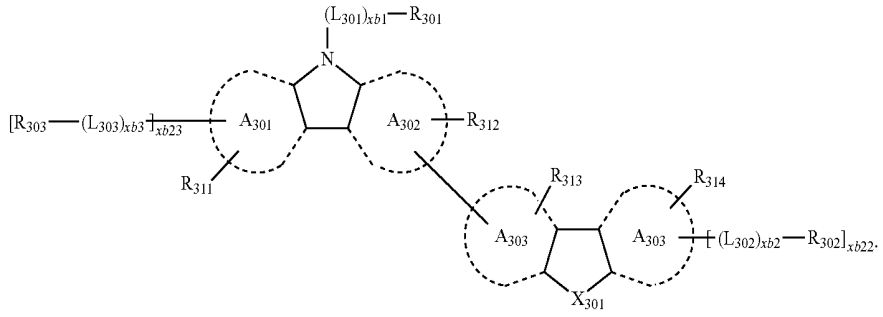
[0199] When xb11 in Formula 301 is two or more, the two or more Ar_{301}(s) may be linked via a single bond.

[0200] In one or more embodiments, the compound represented by Formula 301 may be represented by Formula 301-1 or 301-2:

Formula 301-1



Formula 301-2



[0201] In Formulae 301-1 and 301-2,

[0202] 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,

[0203] X_{301} may be O, S, or $N—[(L_{304})_{xb4}—R_{304}]$

[0204] 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 $—P(=O)(Q_{31})(Q_{32})$,

[0205] xb22 and xb23 may each be 0, 1, or 2,

[0206] L_{301}, xb1, R_{301}, and Q_{31} to Q_{33} may each independently be the same as described above,

[0207] L_{302} to L_{304} may each independently be the same as described in connection with L_{301},

[0208] xb2 to xb4 may each independently be the same as described in connection with xb1, and

[0209] R_{302} to R_{304} may each independently be the same as described in connection with R_{301}.

[0210] For example, in Formulae 301, 301-1, and 301-2, L_{301} to L_{304} may each independently be selected from:

[0211] 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 diben-

zofuranylene 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

[0212] 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

[0213] Q_{31} to Q_{33} may each independently be the same as described above.

[0214] In one or more embodiments, in Formulae 301, 301-1, and 301-2, R_{301} to

[0215] R_{304} may each independently be selected from:

[0216] 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 pyrimidyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoalinyl group, a quinozolinyl 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

[0217] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluoroenyl group, a dibenzofluoroenyl 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 benzamidazolyl group, an isobenzothiazolyl group, a benzoxazolyl

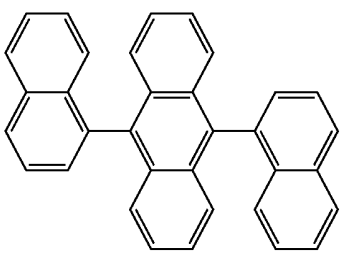
group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a 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, 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

[0218] Q_{31} and Q_{33} may each independently be the same as described above.

[0219] In one or more embodiments, the host may include an alkaline earth metal complex. For example, the host may be selected from a beryllium (Be) complex (for example, Compound H55) and a magnesium (Mg) complex. In some embodiments, the host may be a Zn complex.

[0220] The host may include at least one selected from 9,10-di(2-naphthyl)anthracene (ADN), 2-methyl-9,10-bis(naphthalen-2-yl)anthracene (MADN), 9,10-di-(2-naphthyl)-2-t-butyl-anthracene (TBADN), 4,4'-bis(N-carbazolyl)-1,1'-biphenyl (CBP), 1,3-di-9-carbazolylbenzene (mCP), 1,3,5-tri(carbazol-9-yl)benzene (TCP), and Compounds H1 to H55, but embodiments of the present disclosure are not limited thereto:

H1



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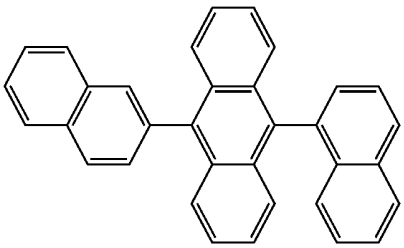

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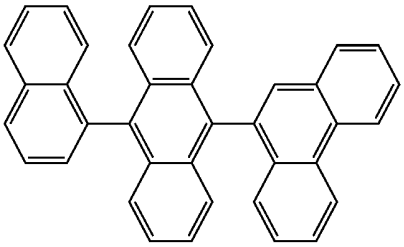

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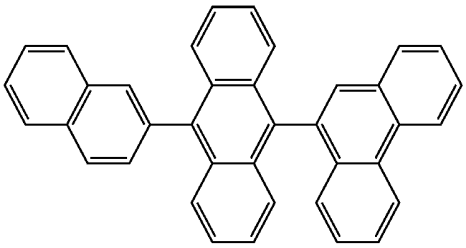

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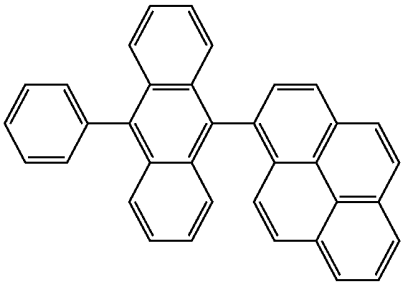

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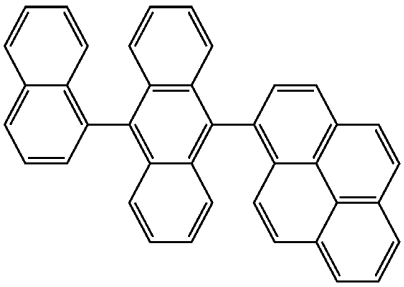

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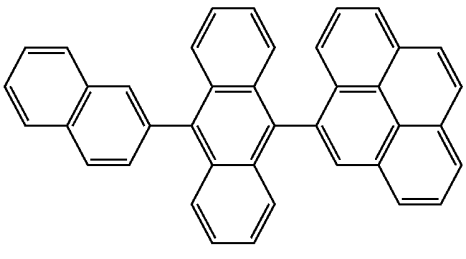

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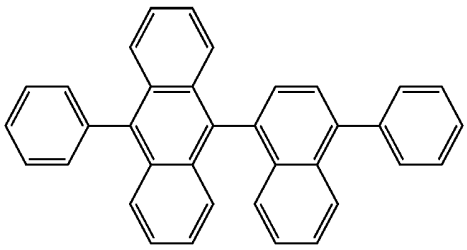

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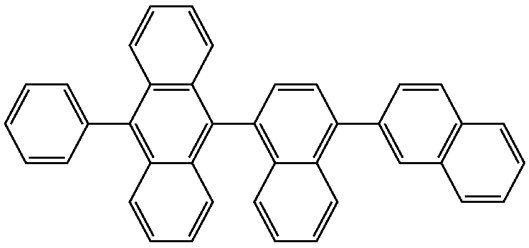

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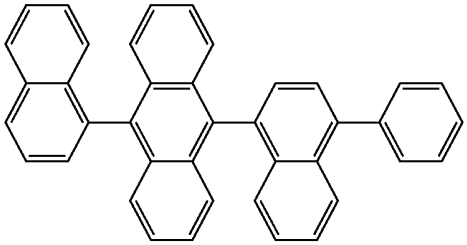

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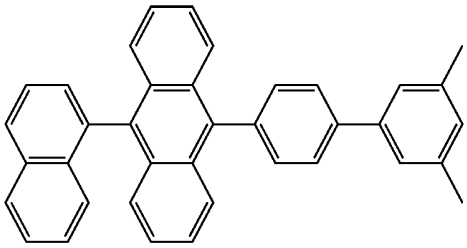

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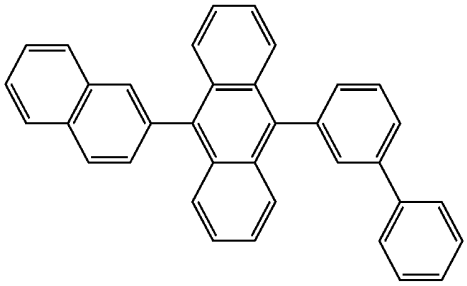

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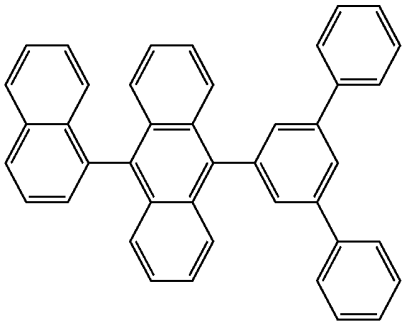

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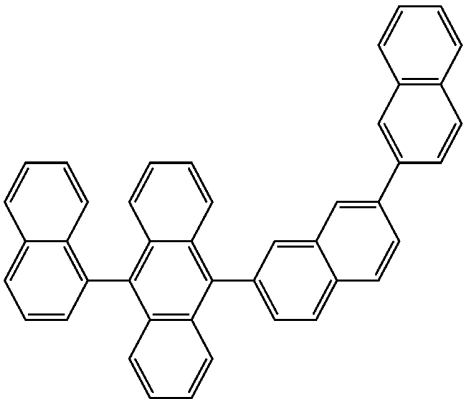

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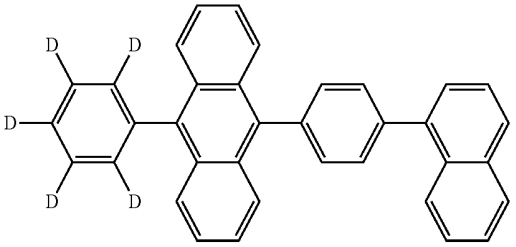

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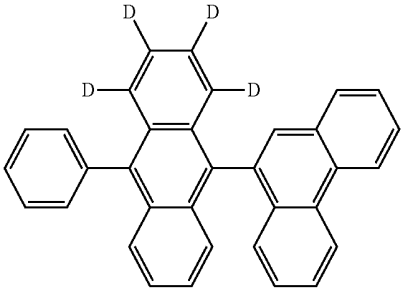

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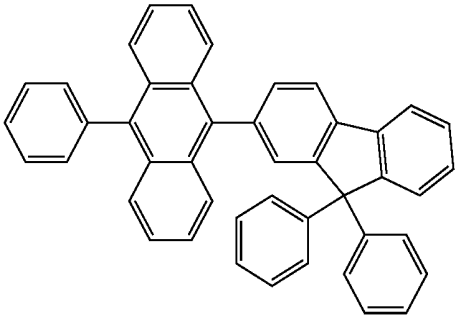

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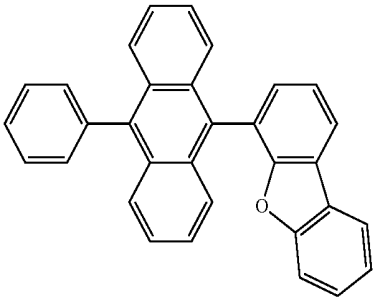

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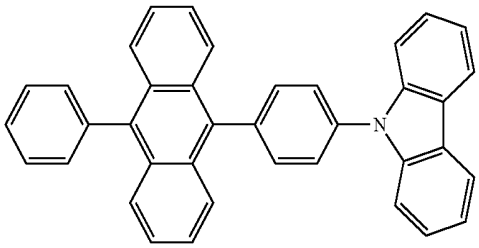

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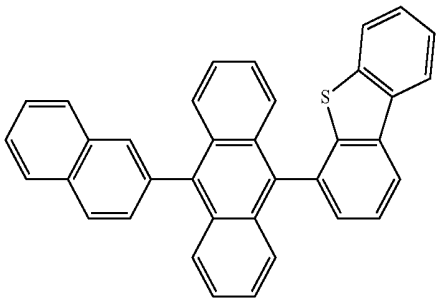

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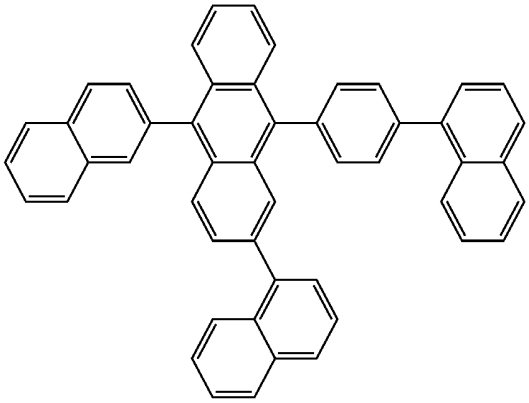

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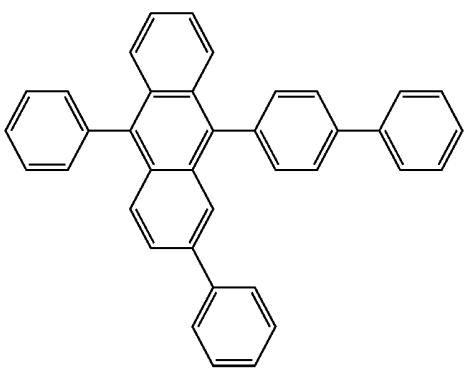

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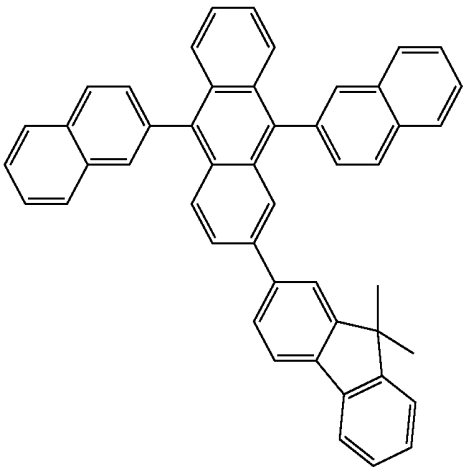

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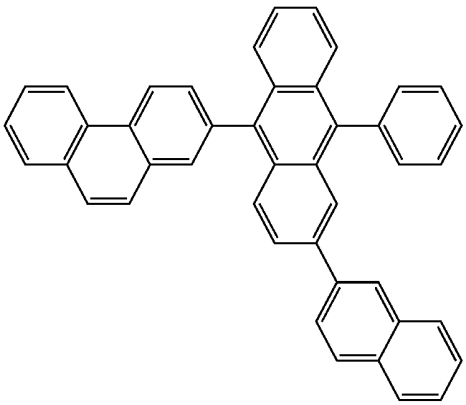

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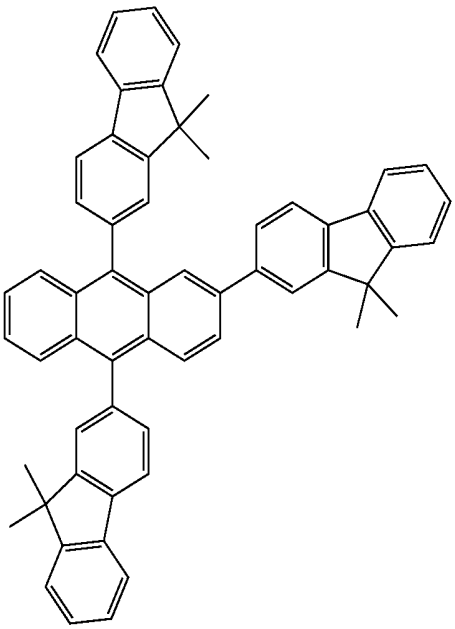

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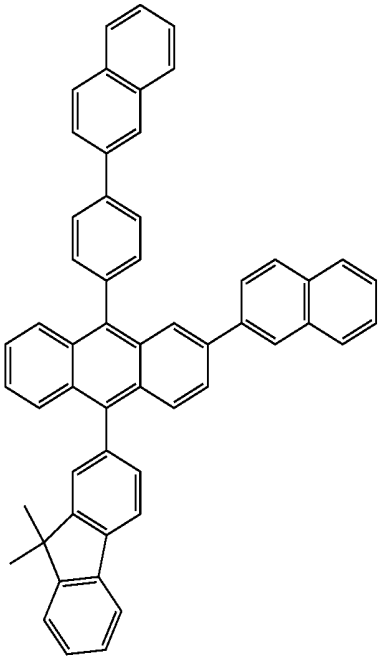

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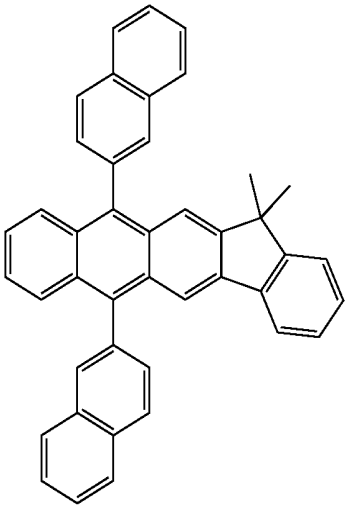

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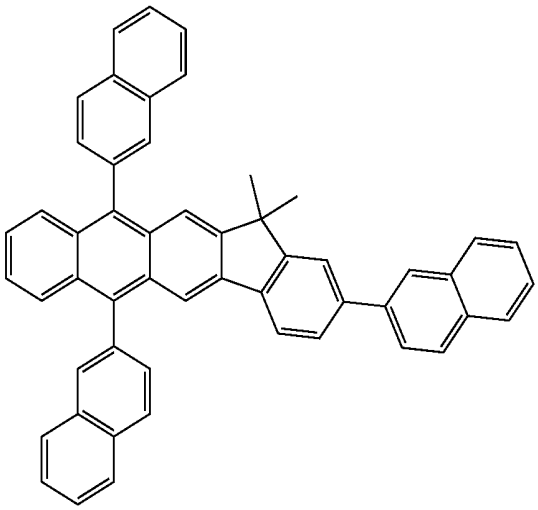

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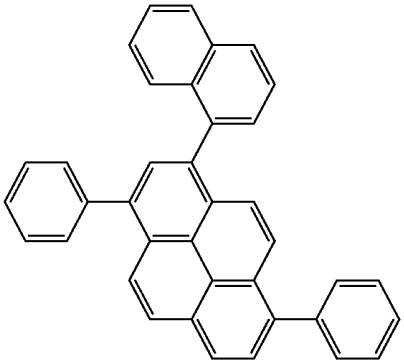

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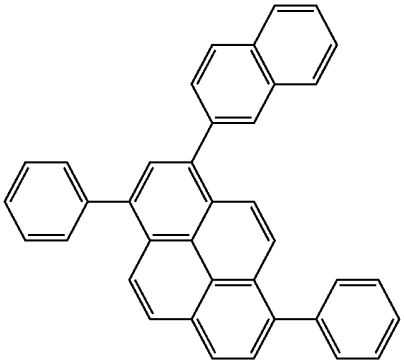

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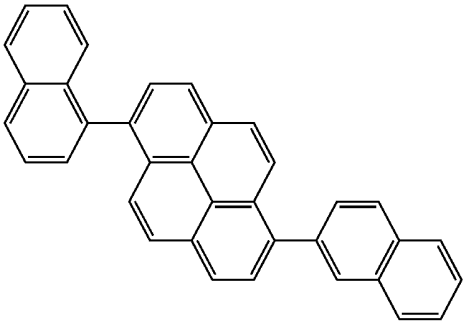

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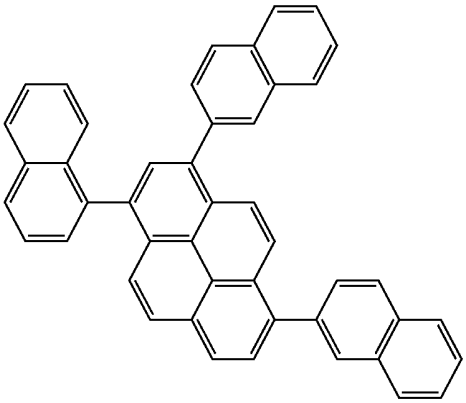

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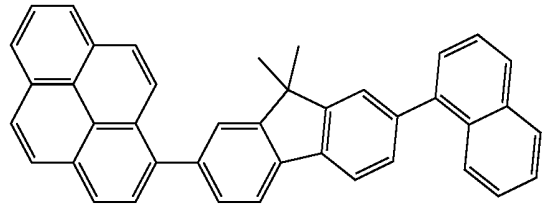

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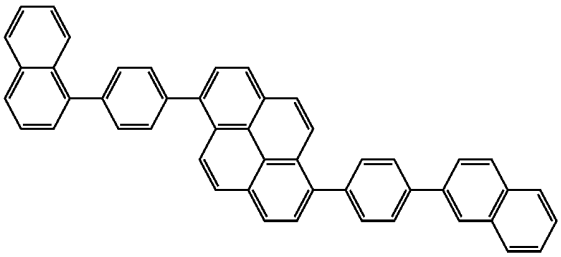

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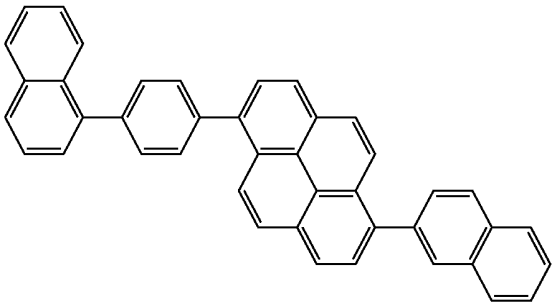

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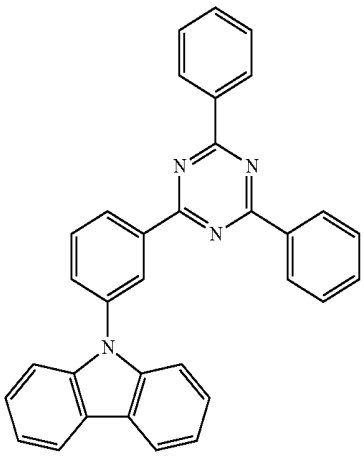

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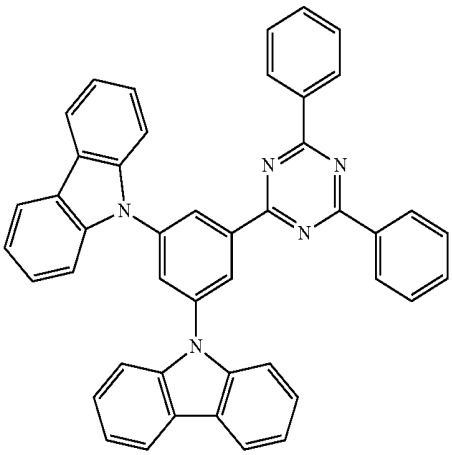

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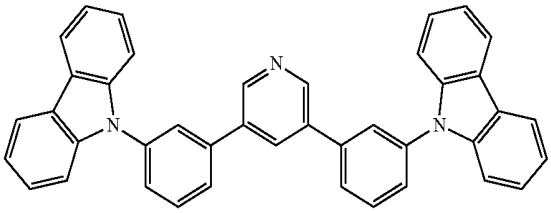

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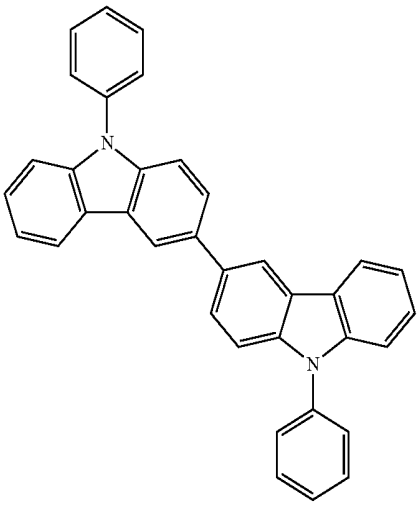

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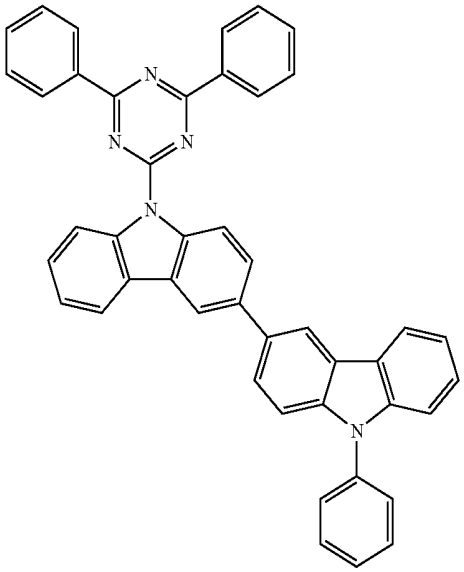

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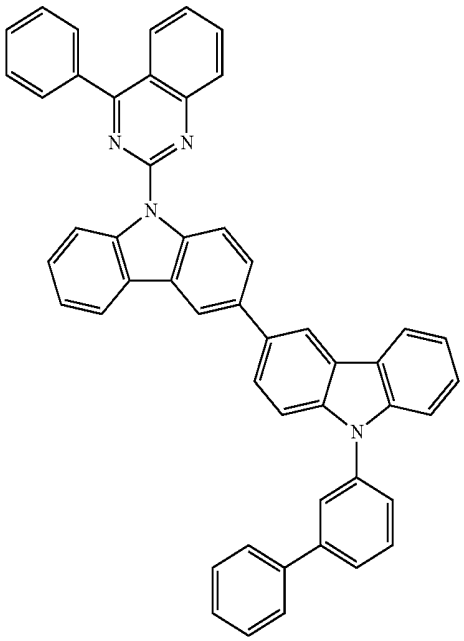

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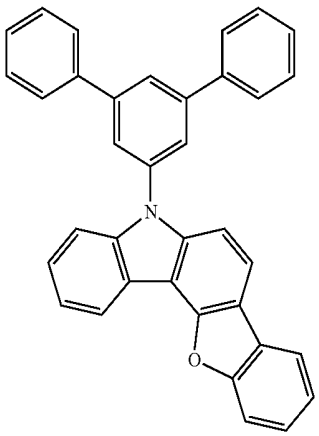

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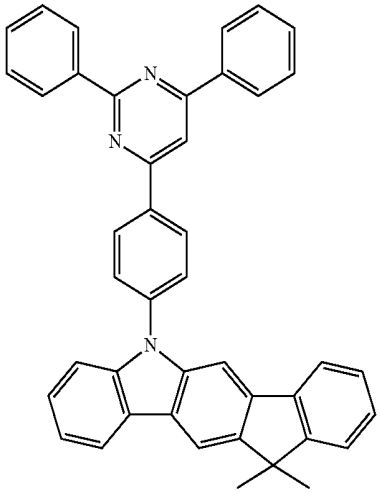

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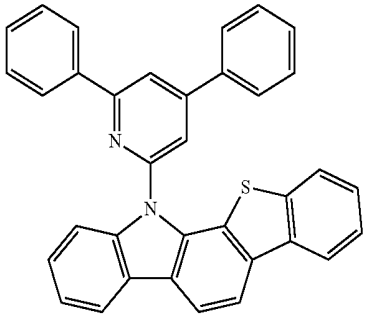

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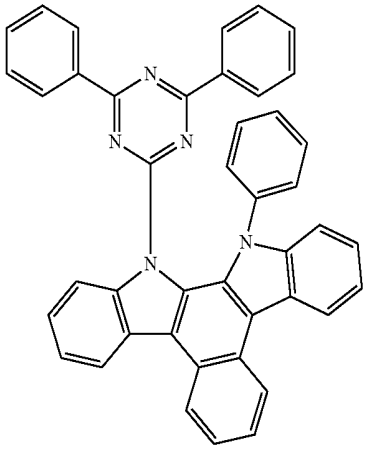

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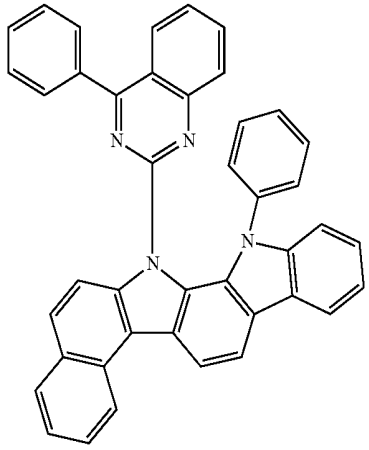

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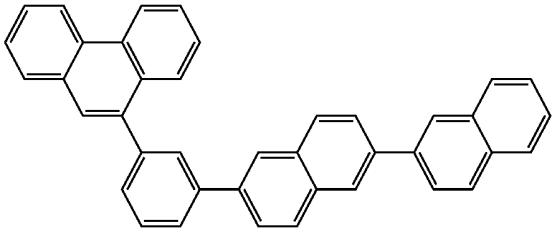

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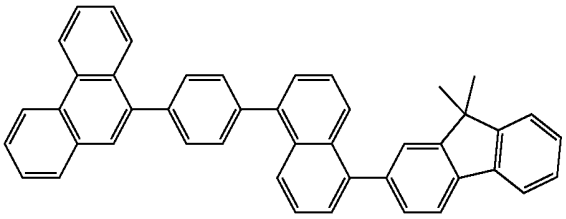

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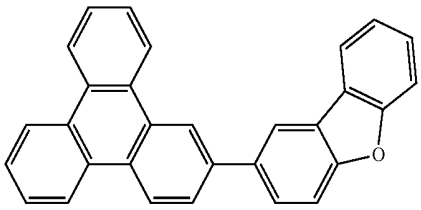

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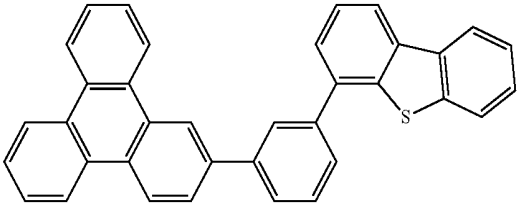

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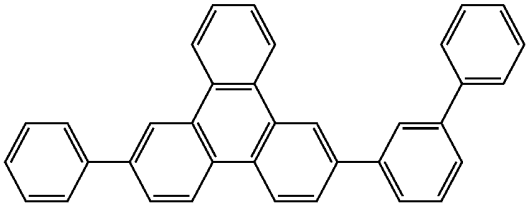

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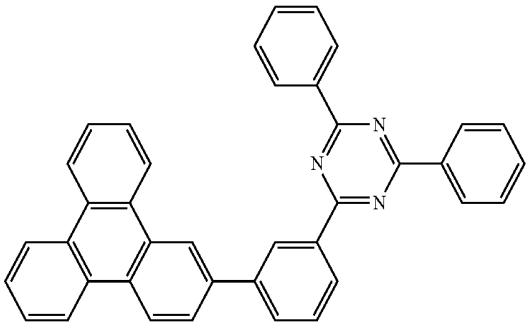

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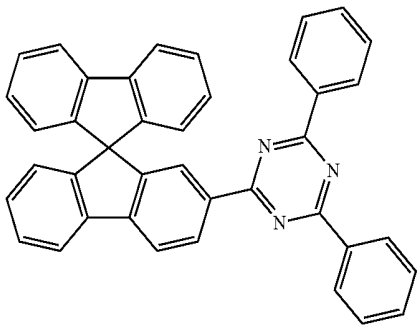

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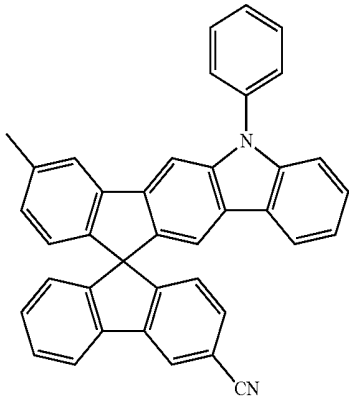

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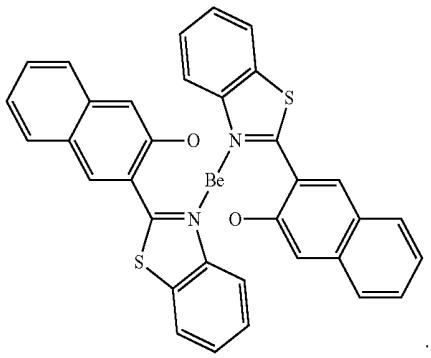


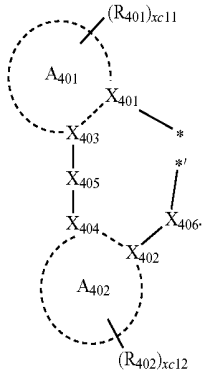
Phosphorescent Dopant Included in Emission Layer in Organic Layer **150**

[0221] The phosphorescent dopant may include an organometallic complex represented by Formula 401:

Formula 401

$$M(L_{401})_{xc1}(L_{402})_{xc2},$$

Formula 402



[0222] In Formulae 401 and 402,

[0223] 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),

[0224] 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,

[0225] 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,

[0226] X_{401} to X_{404} may each independently be nitrogen or carbon,

[0227] 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,

[0228] A_{401} and A_{402} may each independently be selected from a C_5-C_{60} carbocyclic group and a C_1-C_{60} heterocyclic group,

[0229] 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})=*', wherein 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,

[0230] X_{406} may be a single bond, O, or S,

[0231] R_{401} and R_{402} may each be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1-C_{20} alkyl group, a substituted or unsubstituted C_1-C_{20} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(Q_{401})(Q_{402})(Q_{403}), —N(Q_{401})(Q_{402}), —B(Q_{401})(Q_{402}), —C(=O)(Q_{401}), —S(=O)$_2$(Q_{401}), and —P(=O)(Q_{401})(Q_{402}),

[0232] 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,

[0233] xc1 and xc12 may each be an integer from 0 to 10, and

[0234] * and *' in Formula 402 may each indicate a binding site to M of Formula 401.

[0235] 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.

[0236] 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.

[0237] In one or more embodiments, in Formula 402, R_{401} and R_{402} may each be selected from:

[0238] 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;

[0239] 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;

[0240] 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;

[0241] 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; and

[0242] $—Si(Q_{401})(Q_{402})(Q_{403})$, $—N(Q_{401})(Q_{402})$, $—B(Q_{401})(Q_{402})$, $—C(=O)(Q_{401})$, $—S(=O)_2(Q_{401})$, and $—P(=O)(Q_{401})(Q_{402})$, and

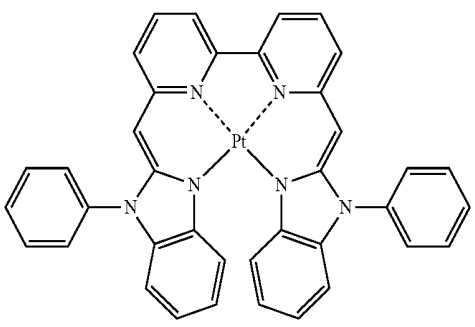
[0243] Q_{401} to Q_{403} may each independently be selected from a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, and a naphthyl group, but embodiments of the present disclosure are not limited thereto.

[0244] In one or more embodiments, when xc1 in Formula 401 is two or more, the two A_{401}(s) in two or more L_{401}(s) may optionally be linked via X_{407}, which is a linking group, and/or the 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), but embodiments of the present disclosure are not limited thereto.

[0245] L_{402} in Formula 401 may be a monovalent, divalent, or trivalent organic ligand. For example, L_{402} may be a halogen, a diketone (for example, acetylacetonate), a carboxylic acid (for example, picolinate), —C(=O), an isonitrile, —CN, and a phosphorus group (for example, phosphine and phosphite), but embodiments of the present disclosure are not limited thereto.

[0246] In one or more embodiments, the phosphorescent dopant may be selected from, for example, Compounds PD1 to PD25, but embodiments of the present disclosure are not limited thereto:

PD1



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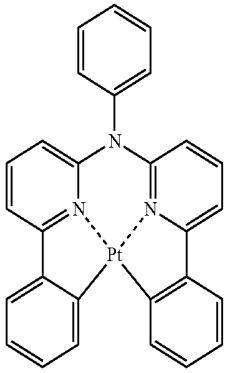
PD2



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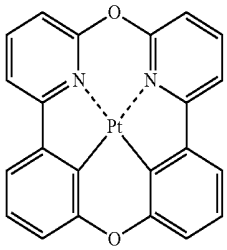

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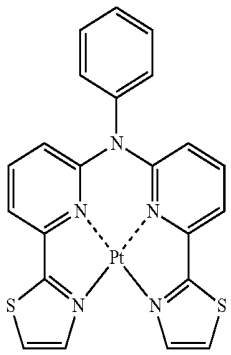

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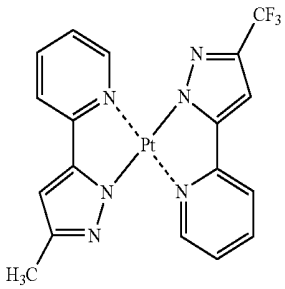

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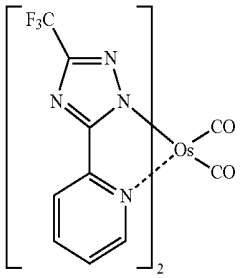

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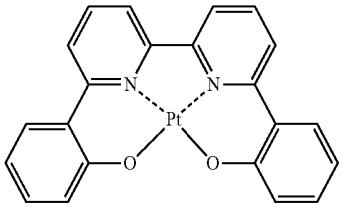

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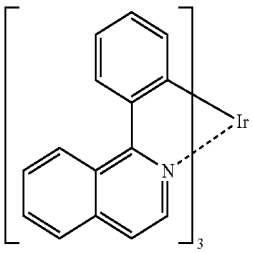

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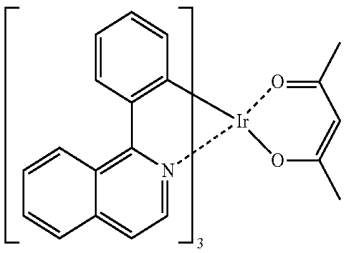

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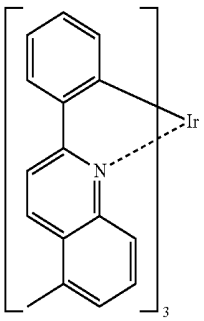

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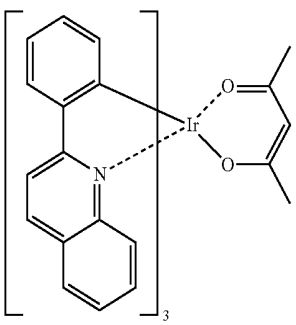

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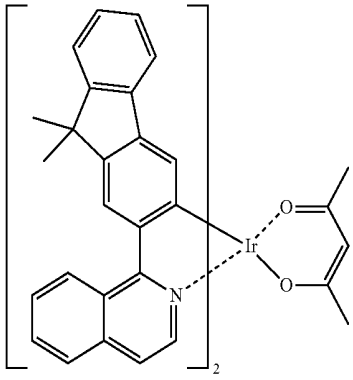

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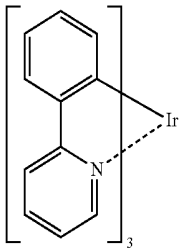

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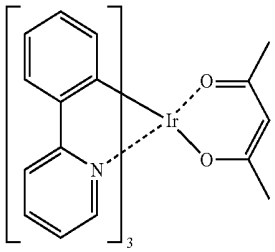

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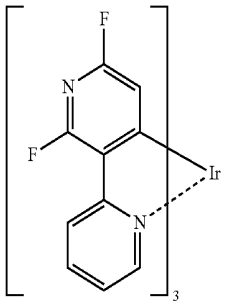

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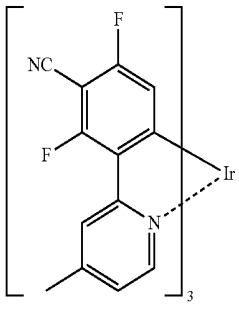

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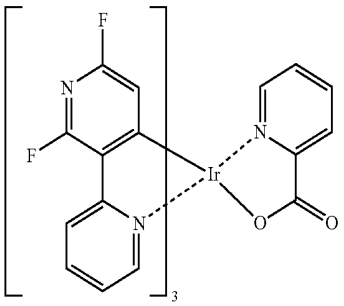

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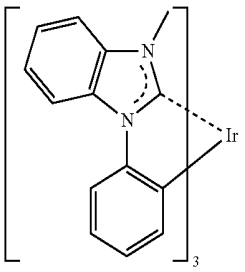

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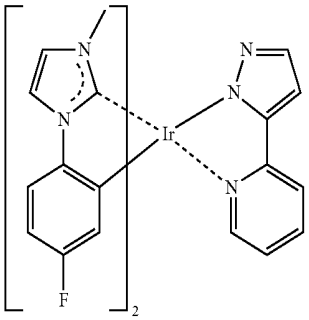

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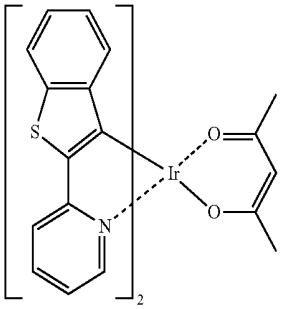

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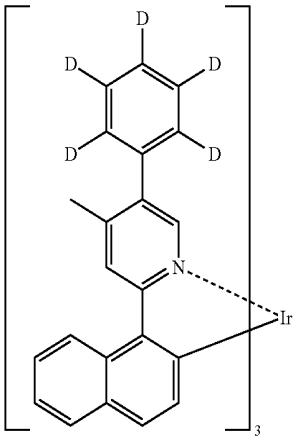

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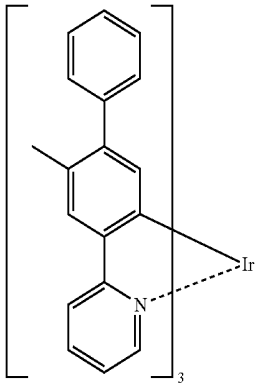

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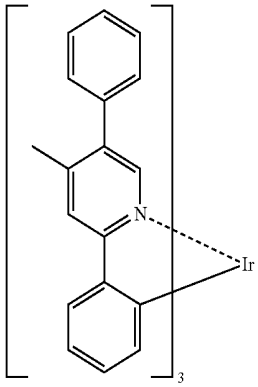

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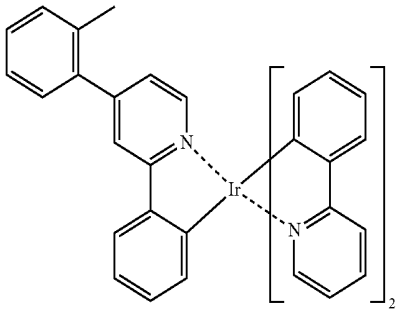

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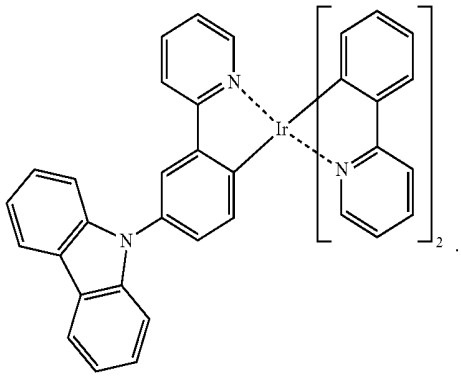


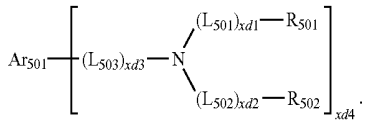
Fluorescent Dopant in Emission Layer

[0247] The fluorescent dopant may include the condensed cyclic compound represented by Formula 1.

[0248] In one or more embodiments, the fluorescent dopant may further include an arylamine compound or a styrylamine compound.

[0249] The fluorescent dopant may include a compound represented by Formula 501:

Formula 501



[0250] In Formula 501,

[0251] 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,

[0252] 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,

[0253] xd1 to xd3 may each independently be an integer of 0 to 3;

[0254] 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

[0255] xd4 may be an integer of 1 to 6.

[0256] In one or more embodiments, Ar_{501} in Formula 501 may be selected from:

[0257] 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

[0258] 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.

[0259] In one or more embodiments, L_{501} to L_{503} in Formula 501 may each independently be selected from:

[0260] 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; and

[0261] 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.

[0262] In one or more embodiments, in Formula 501, R_{501} and R_{502} may each independently be selected from:

[0263] 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; and

[0264] 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

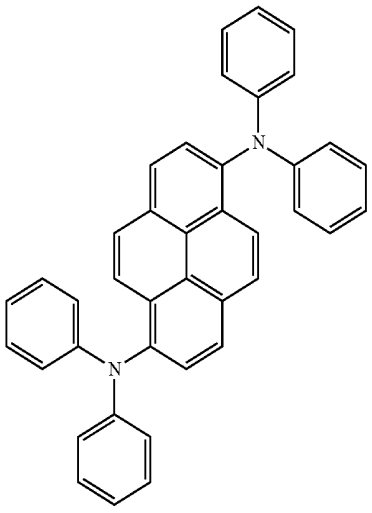
dibenzosilolyl group, and a pyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl 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

[0265] 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.

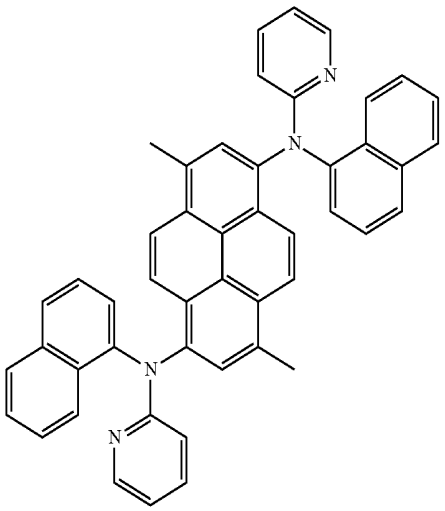
[0266] In one or more embodiments, xd4 in Formula 501 may be 2, but embodiments of the present disclosure are not limited thereto.

[0267] For example, the fluorescent dopant may be selected from Compounds FD1 to FD22:

FD1



FD2



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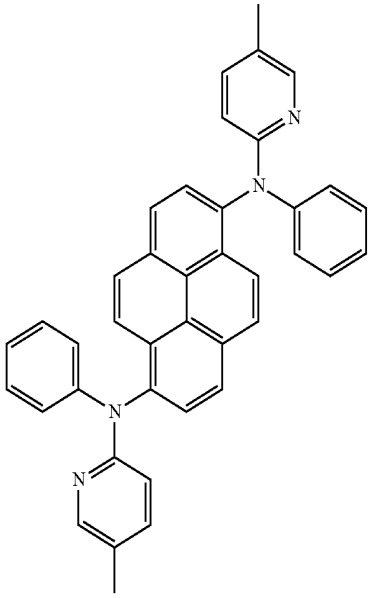
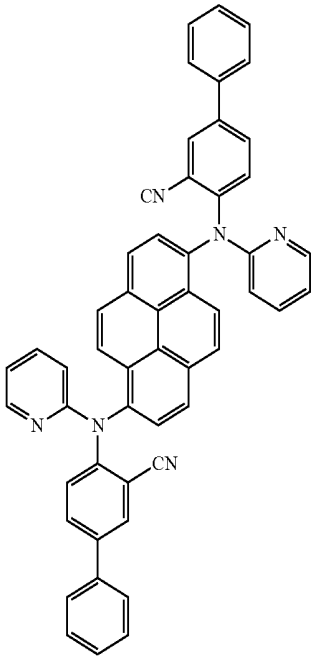
FD3



FD4



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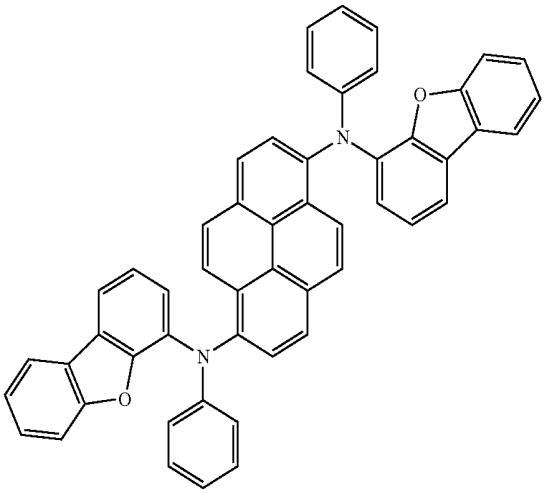
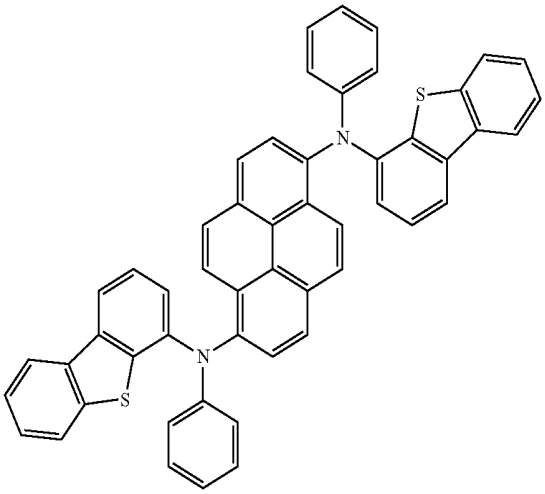
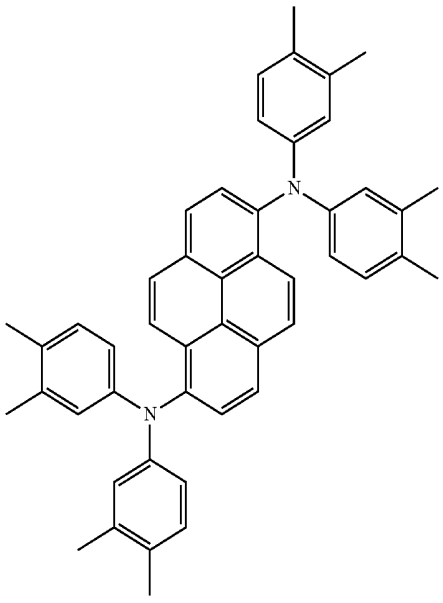
FD5



FD6



FD7



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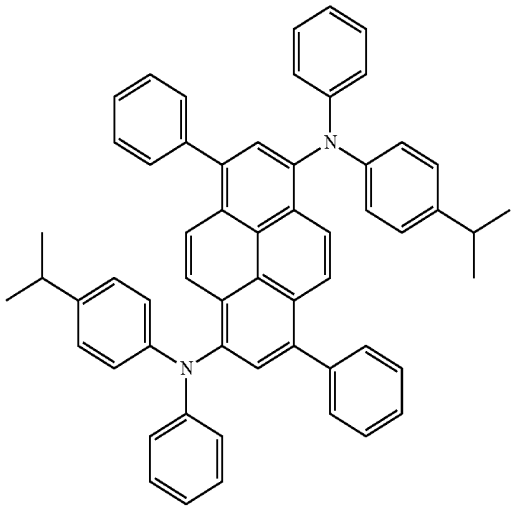
FD8



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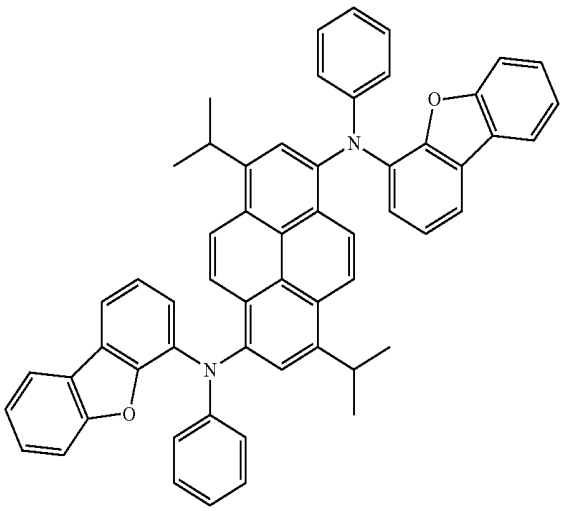
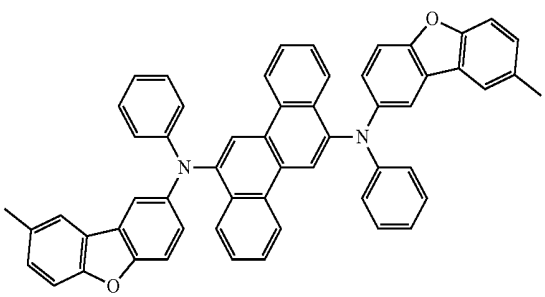


FD10



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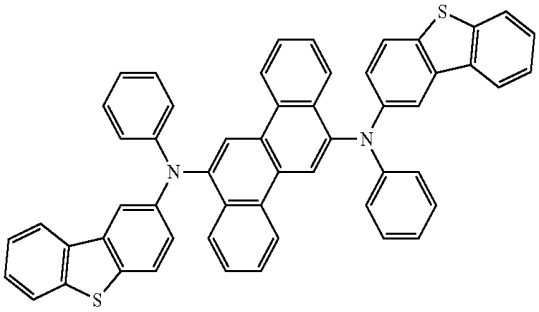
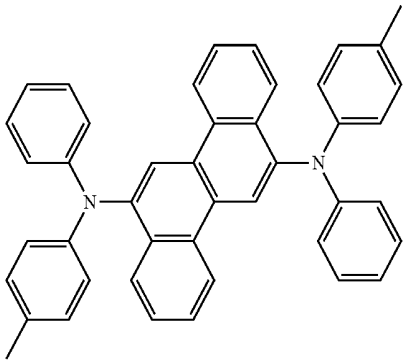
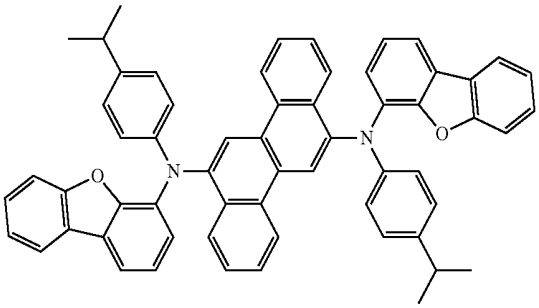
FD11



FD12



FD13



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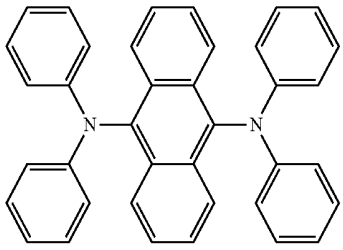
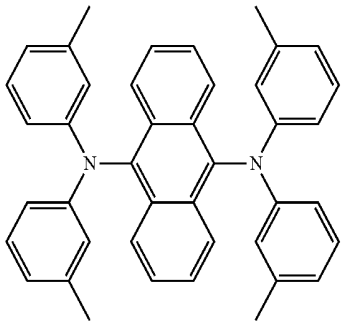


FD15



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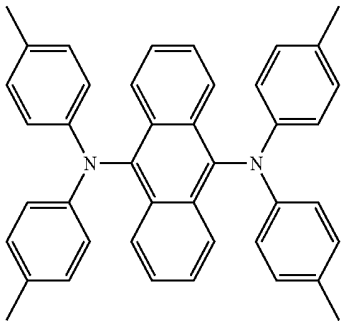
FD16



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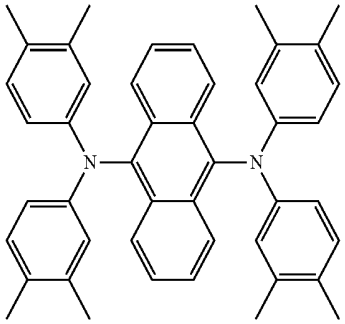

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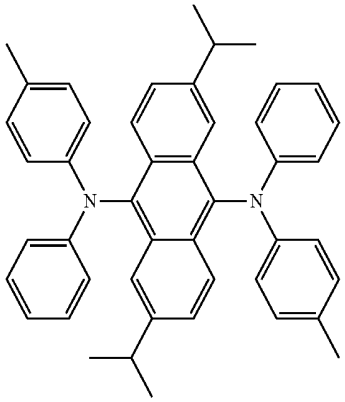
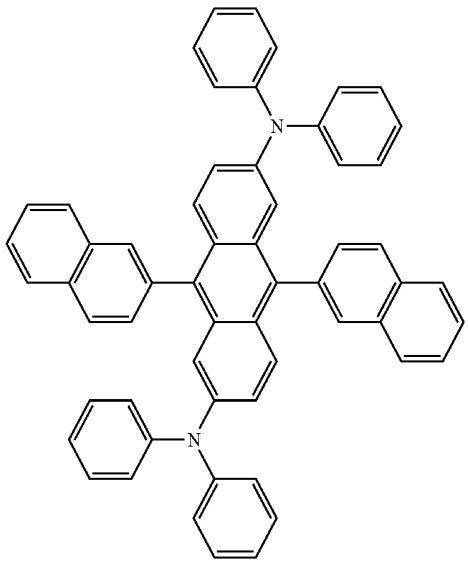


FD19



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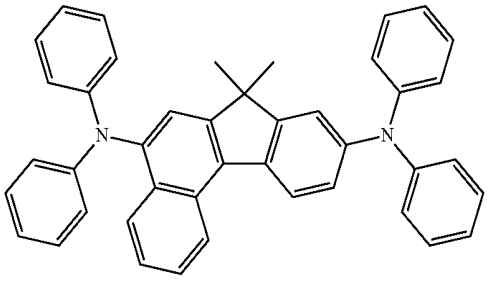
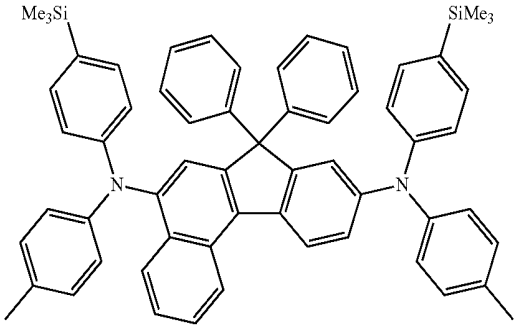
FD20



FD21



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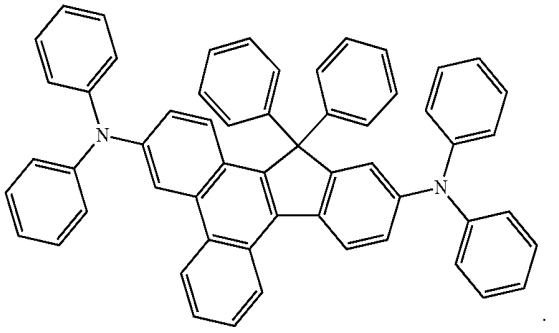
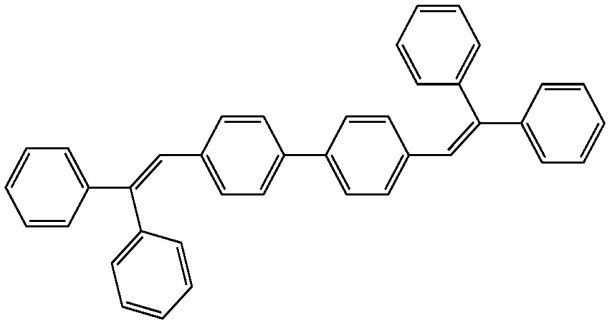
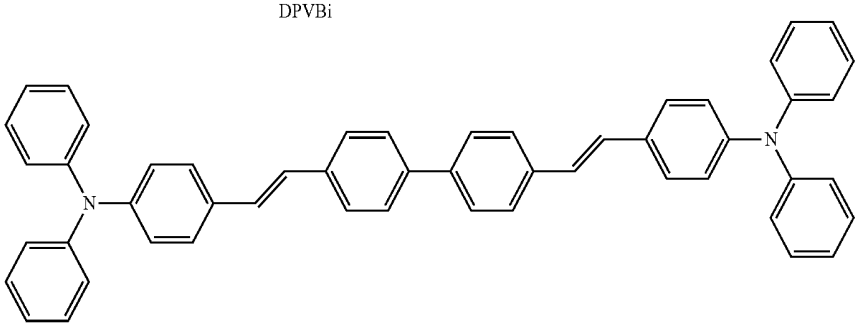
FD22



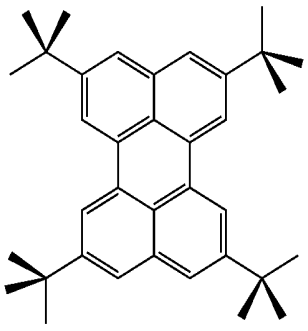
[0268] In one or more embodiments, the fluorescent dopant may be selected from the following compounds, but embodiments of the present disclosure are not limited thereto.



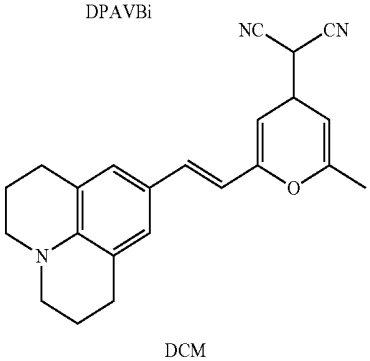
DPVBi



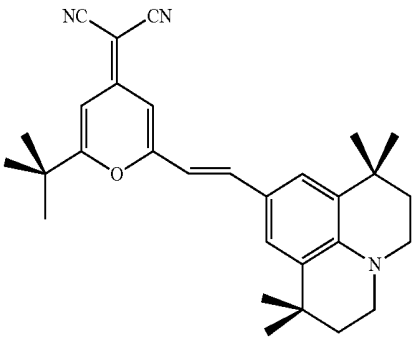
DPAVBi



TBPe



DCM



DCJTB

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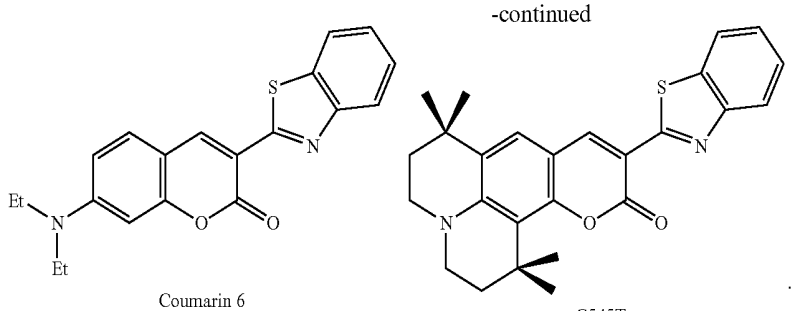


Coumarin 6

C545T

Electron Transport Region in Organic Layer **150**

[0269] The electron transport region may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

[0270] The electron transport region may include at least one selected from a buffer layer, a hole blocking layer, an electron control layer, an electron transport layer, and an electron injection layer, but embodiments of the present disclosure are not limited thereto.

[0271] For example, the electron transport region may have an electron transport layer/electron injection layer structure, a hole blocking layer/electron transport layer/electron injection layer structure, an electron control layer/electron transport layer/electron injection layer structure, or a buffer layer/electron transport layer/electron injection layer structure, wherein the constituting layers of each structure are sequentially stacked on the emission layer. However, embodiments of the structure of the electron transport region are not limited thereto.

[0272] The electron transport region (for example, a buffer layer, a hole blocking layer, an electron control layer, and/or an electron transport layer in the electron transport region) may include a metal-free compound including at least one a Tr electron-depleted nitrogen-containing ring.

[0273] 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.

[0274] For example, the "π electron-depleted nitrogen-containing ring" may be i) a 5-membered to 7-membered heteromonocyclic group having at least one *—N=*' moiety, ii) a heteropolycyclic group in which two or more 5-membered to 7-membered heteromonocyclic groups each having at least one *—N=*' moiety are condensed with each other, or iii) a heteropolycyclic group in which at least one of 5-membered to 7-membered heteromonocyclic groups, each having at least one *—N=*' moiety, is condensed with at least one C_5-C_{60} carbocyclic group.

[0275] 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 quinazolirie, 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, a thiadiazole, an imidazopyridine, an imidazopyrimidine, and an azacarbazole, but embodiments of the present disclosure are not limited thereto.

[0276] For example, the electron transport region may include a compound represented by Formula 601:

$$[Ar_{601}]_{xe11}—[(L_{601})_{xe1}—R_{601}]_{xe21}. \quad \text{Formula 601}$$

[0277] In Formula 601,

[0278] 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,

[0279] xe11 may be 1, 2, or 3,

[0280] L_{601} 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;

[0281] xe1 may be an integer from 0 to 5,

[0282] 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 —$P(=O)(Q_{601})(Q_{602})$,

[0283] 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

[0284] xe21 may be an integer from 1 to 5.

[0285] In one or more embodiments, at least one Ar_{601} group and R_{601} group (among the total number of groups provided by xe11 and xe21) may include the π electron-depleted nitrogen-containing ring.

[0286] In one or more embodiments, ring Ar_{601} in Formula 601 may be selected from:

[0287] 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 triph-

enylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, a dibenzothiophene group, a carbazole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, a naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, a phenanthroline group, a phenazine group, a benzimidazole group, an isobenzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a thiadiazole group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group; and

[0288] a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, a dibenzothiophene group, a carbazole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, a naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, a phenanthroline group, a phenazine group, a benzimidazole group, an isobenzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a thiadiazole group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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

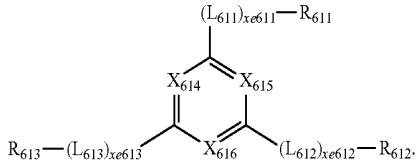
[0289] wherein Q_{31} to Q_{33} may each independently be selected from a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0290] When xe11 in Formula 601 is two or more, the two or more Ar_{601}(s) may be linked via a single bond.

[0291] In one or more embodiments, Ar_{601} in Formula 601 may be an anthracene group.

[0292] In one or more embodiments, a compound represented by Formula 601 may be represented by Formula 601-1:

Formula 601-1



[0293] In Formula 601-1,

[0294] 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,

[0295] L_{611} to L_{613} may each independently be the same as described in connection with L_{601},

[0296] xe611 to xe613 may each independently be the same as described in connection with xe1,

[0297] R_{611} to R_{613} may each independently be the same as described in connection with R_{601},

[0298] 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.

[0299] 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:

[0300] 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

[0301] 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, but embodiments of the present disclosure are not limited thereto.

[0302] In one or more embodiments, xe1 and xe611 to xe613 in Formulae 601 and 601-1 may each independently be 0, 1, or 2.

[0303] In one or more embodiments, R_{601} and R_{611} to R_{613} in Formula 601 and 601-1 may each independently be selected from: a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluoroenyl group, a benzofluoroenyl group, a dibenzolfluoroenyl group, a phenanthrenyl group, an anthracenyl group, a fluoroanthenyl 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, a isothiazolyl group, an oxazolyl group, an isozolyl 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 naphthyrindinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzamidazolyl 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;

[0304] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluoroenyl 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 funranyl 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 dibenzosiloyl 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

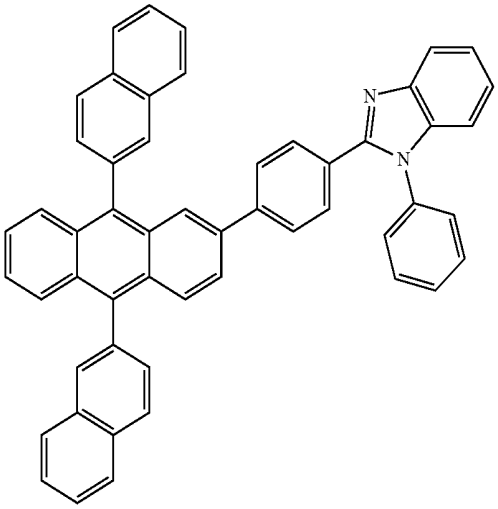
phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group; and

[0305] —$S(=O)_2(Q_{601})$, and —$P(=O)(Q_{601})(Q_{602})$, and

[0306] Q_{601} and Q_{602} may each independently be the same as described above.

[0307] The electron transport region may include at least one compound selected from Compounds ET1 to ET36, but embodiments of the present disclosure are not limited thereto:

ET1



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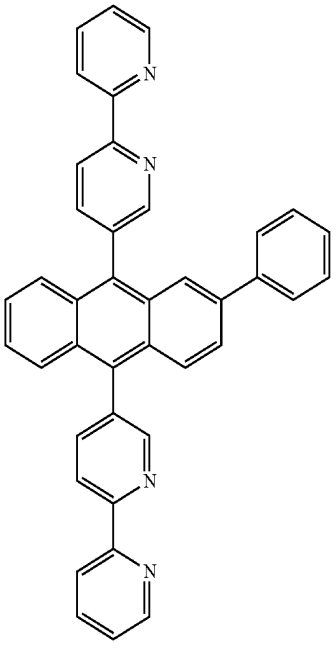

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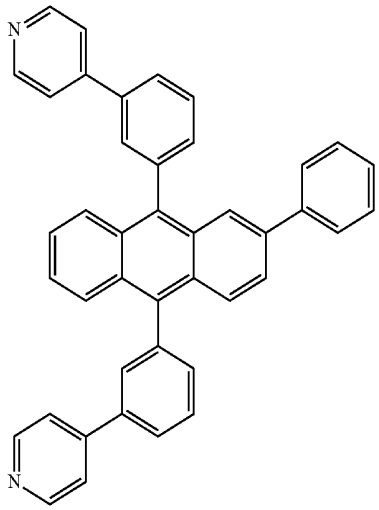
ET3



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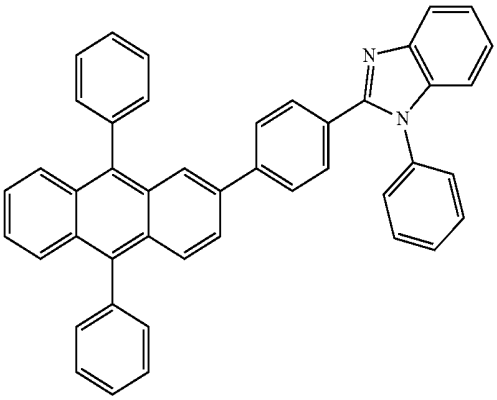

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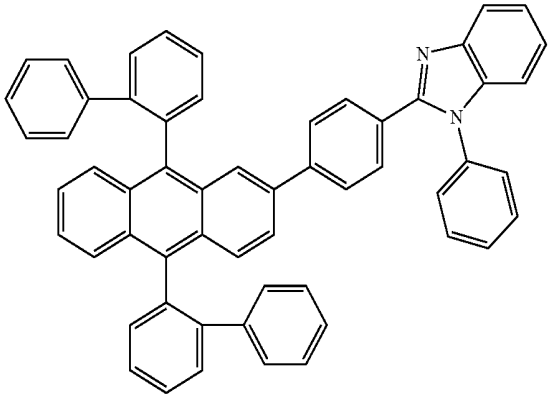

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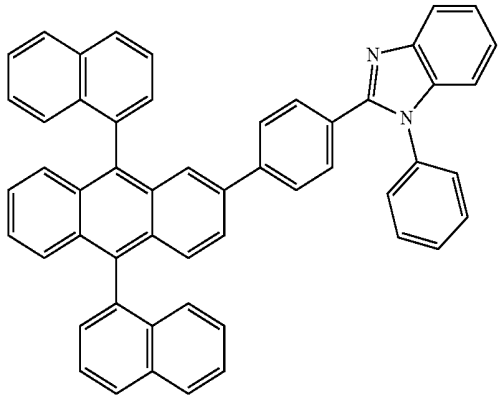

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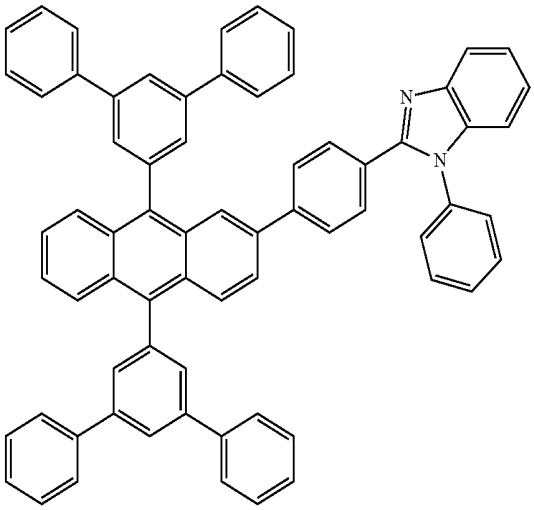

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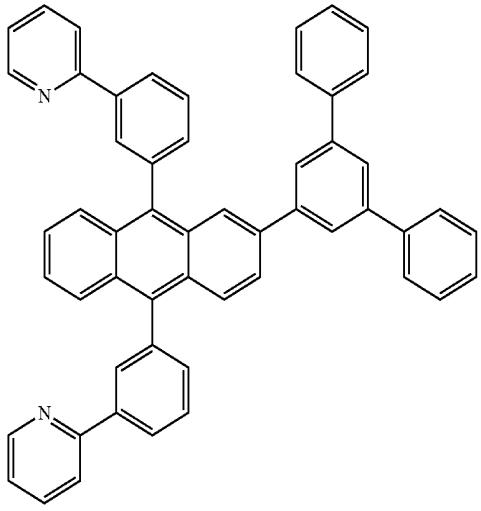

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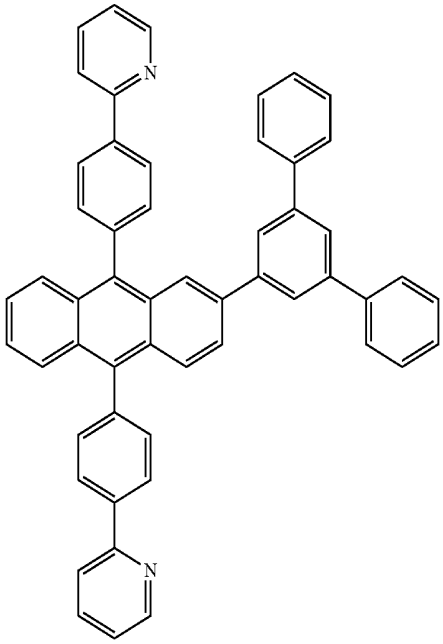

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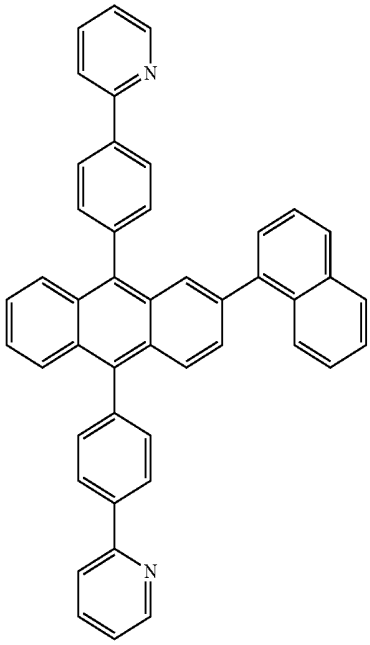

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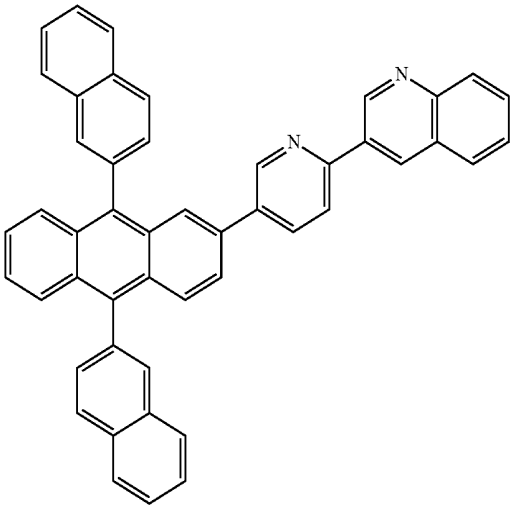

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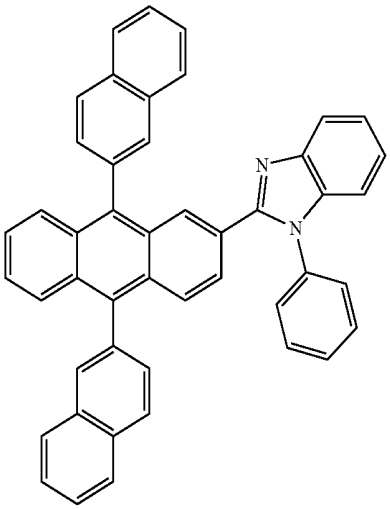

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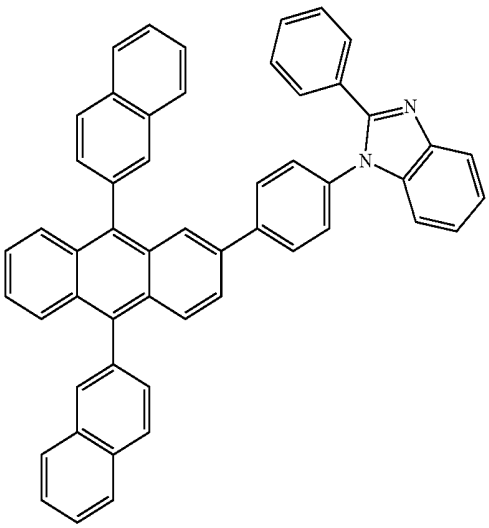

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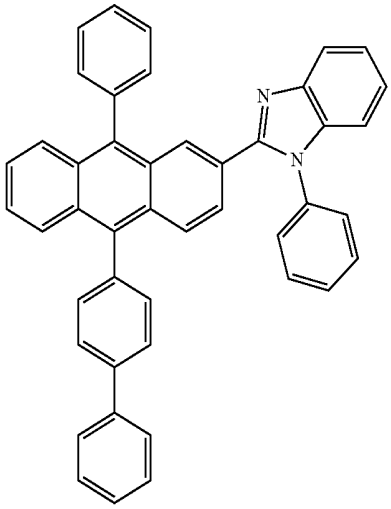

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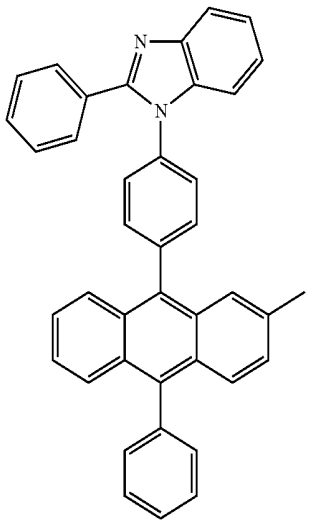

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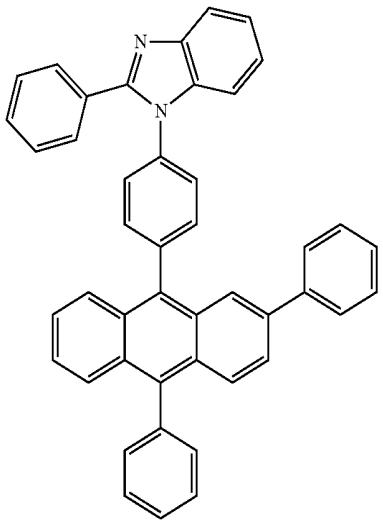

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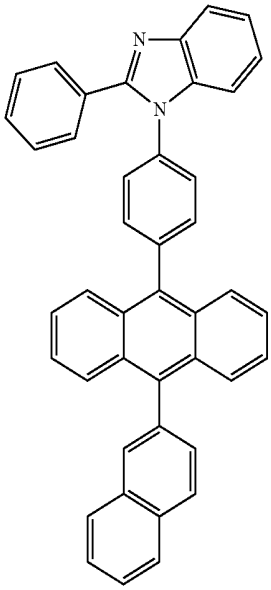

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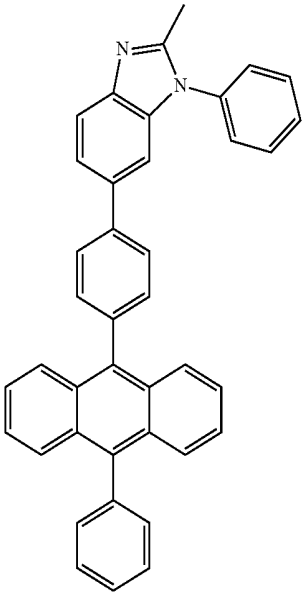

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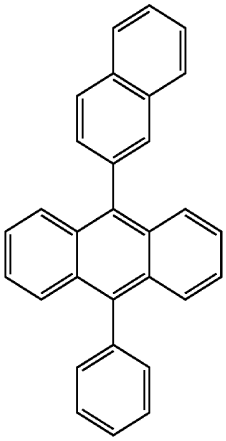

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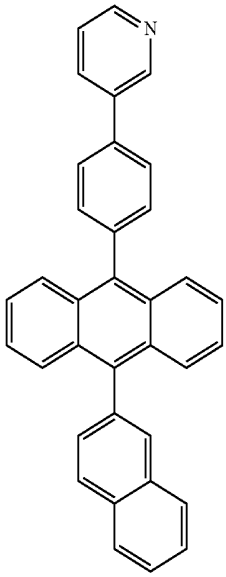

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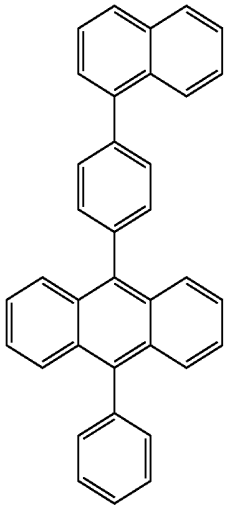

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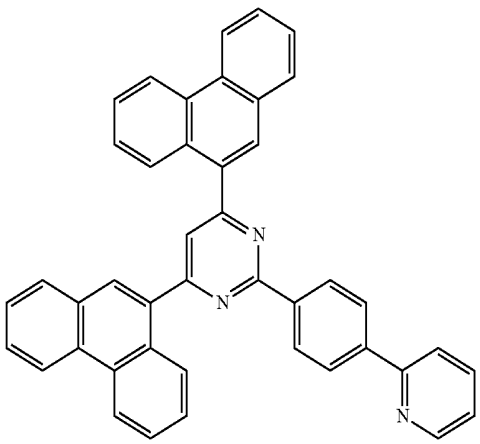

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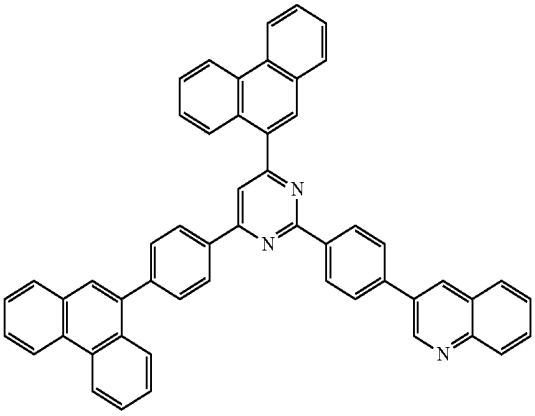

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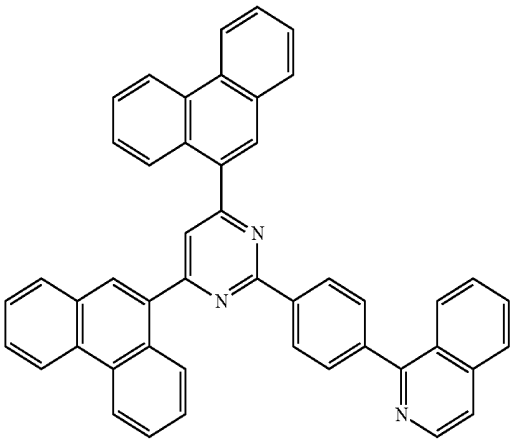

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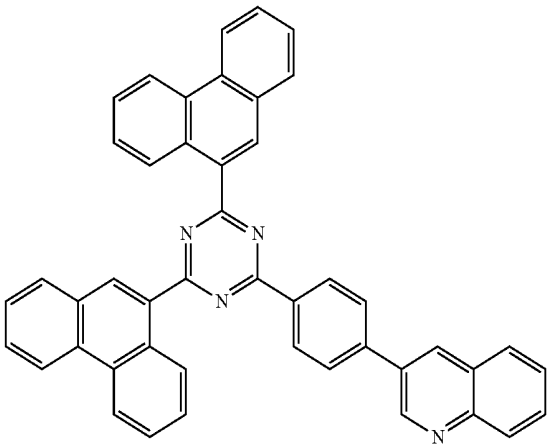

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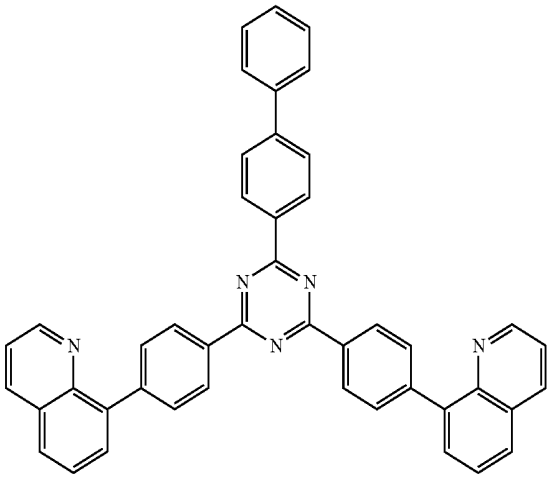
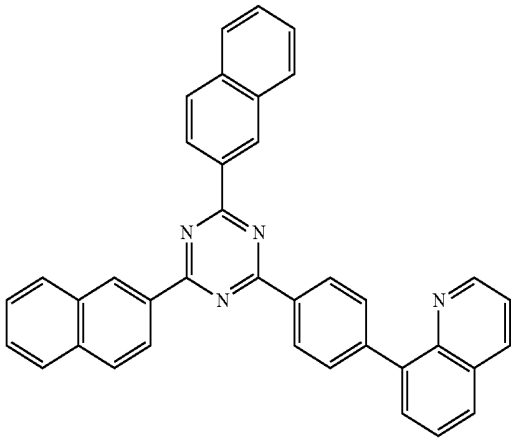
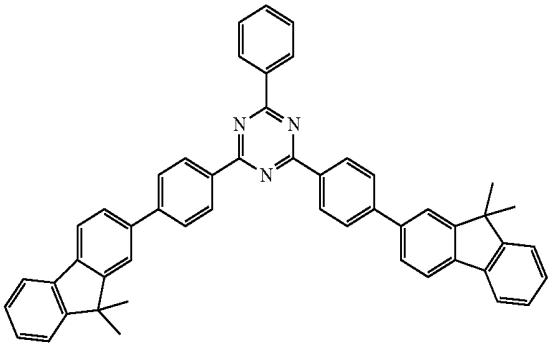
ET26



ET27



ET28



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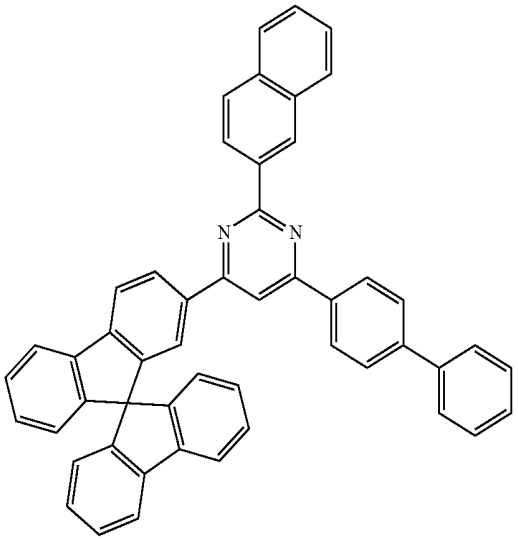
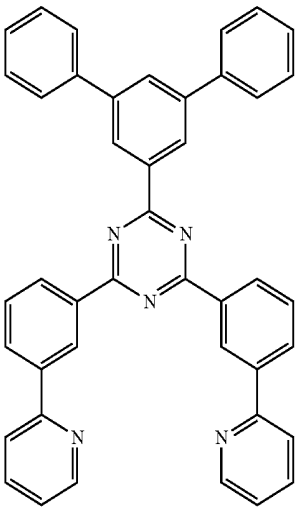
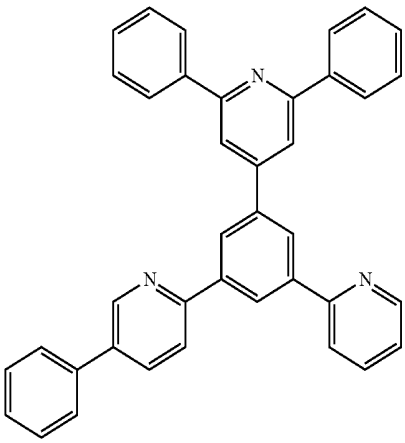
ET29



ET30



ET31



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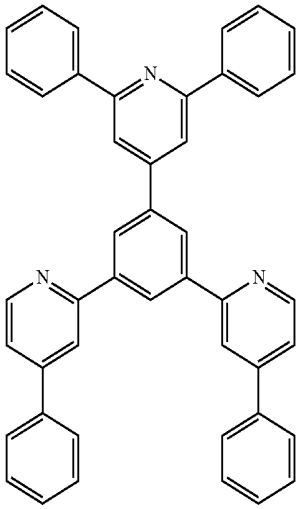
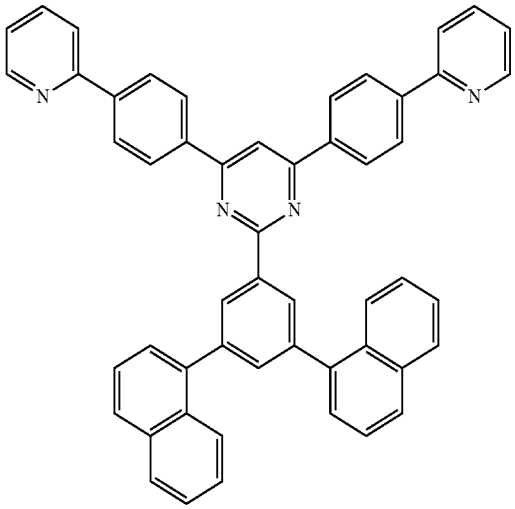
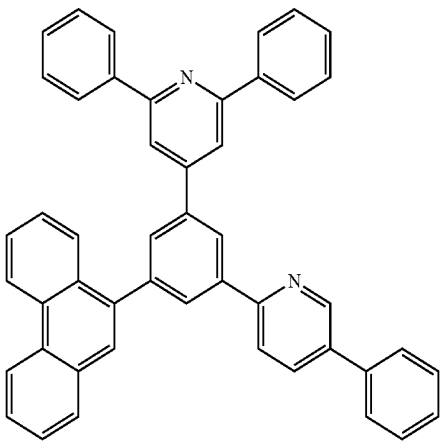
ET32



ET33



ET34



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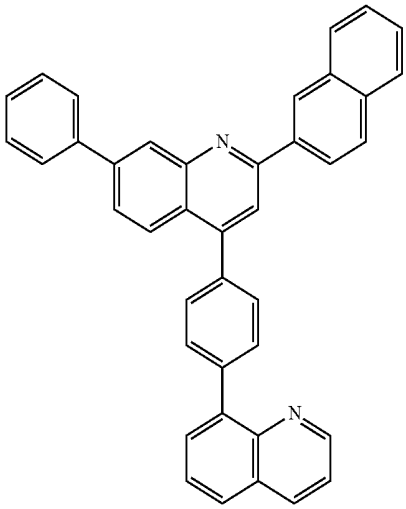
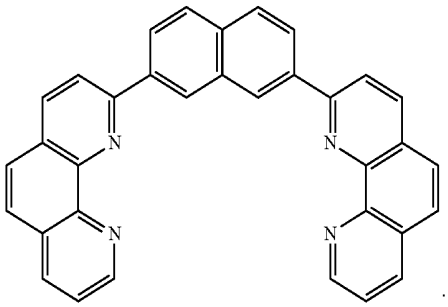
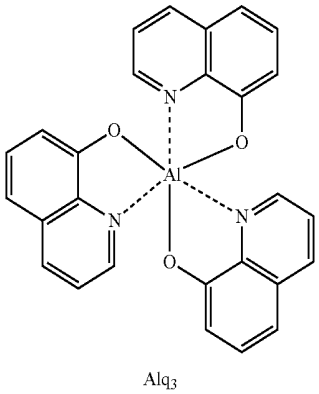
ET35



ET36



[0308] In one or more embodiments, the electron transport region may include at least one compound selected from 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP), 4,7-diphenyl-1,10-phenanthroline (Bphen), Alq3, BAlq, 3-(biphenyl-4-yl)-5-(4-tert-butylphenyl)-4-phenyl-4H-1,2,4-triazole (TAZ), and NTAZ.



Alq_3

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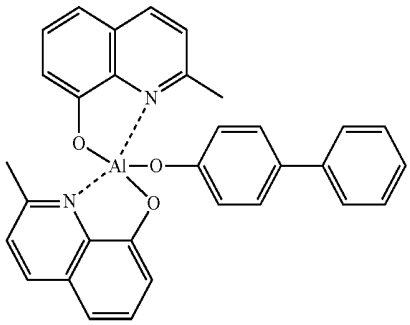
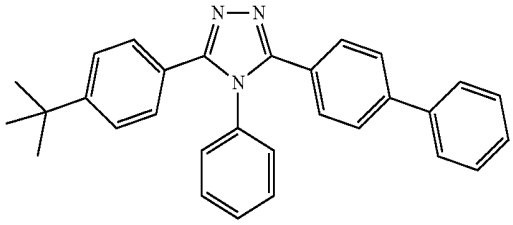
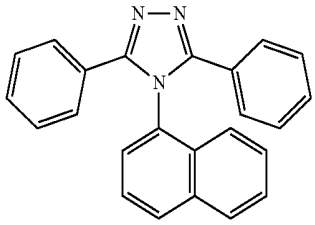


BAlq



TAZ



NTAZ

[0309] The thicknesses of the buffer layer, the hole blocking layer, and/or the electron controlling layer may be about 20 Å to about 1,000 Å, for example, about 30 Å to about 300 Å. When the thicknesses of each 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.

[0310] The thickness of the electron transport layer may be about 100 Å to about 1,000 Å, for example, about 150 Å to about 500 Å. When the thickness of the electron transport layer is within the range described above, the electron transport layer may have satisfactory electron transport characteristics without a substantial increase in driving voltage.

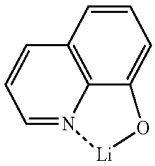
[0311] The electron transport region (for example, the electron transport layer in the electron transport region) may further include, in addition to the materials described above, a metal-containing material.

[0312] The metal-containing material may include at least one selected from an alkali metal complex and an alkaline earth-metal complex. The alkali metal complex may include a metal ion selected from a Li ion, a Na ion, a K ion, a Rb ion, and a Cs ion, and the alkaline earth-metal complex may include a metal ion selected from a Be ion, a Mg ion, a Ca ion, a Sr ion, and a Ba ion. A ligand coordinated with the metal ion of the alkali metal complex or the alkaline earth-metal complex may be selected from a hydroxy quinoline, a hydroxy isoquinoline, a hydroxy benzoquinoline, a hydroxy acridine, a hydroxy phenanthridine, a hydroxy phenyloxazole, a hydroxy phenylthiazole, a hydroxy phe-

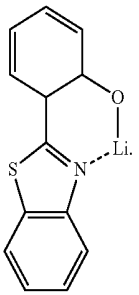
nyloxadiazole, a hydroxy phenylthiadiazole, a hydroxy phenylpyridine, a hydroxy phenylbenzimidazole, a hydroxy phenylbenzothiazole, a bipyridine, a phenanthroline, and a cyclopentadiene, but embodiments of the present disclosure are not limited thereto.

[0313] For example, the metal-containing material may include a Li complex. The Li complex may include, for example, Compound ET-D1 (lithium quinolate, LiQ) or ET-D2.

ET-D1



ET-D2



[0314] The electron transport region may include an electron injection layer that facilitates injection of electrons from the second electrode **190**. The electron injection layer may directly contact the second electrode **190**.

[0315] 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.

[0316] 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.

[0317] The alkali metal may be selected from Li, a Na, K, Rb, and Cs. In one or more embodiments, the alkali metal may be Li, a Na, or Cs. In one or more embodiments, the alkali metal may be Li or Cs, but embodiments of the present disclosure are not limited thereto.

[0318] The alkaline earth metal may be selected from Mg, Ca, Sr, and Ba.

[0319] The rare earth metal may be selected from Sc, Y, Ce, Tb, Yb, and Gd.

[0320] 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.

[0321] The alkali metal compound may be selected from alkali metal oxides, such as Li_2O, Cs_2O, or K_2O, and alkali metal halides, such as LiF, NaF, CsF, KF, LiI, NaI, CsI, or KI. In one or more embodiments, the alkali metal compound may be selected from LiF, Li_2O, NaF, LiI, NaI, CsI, and KI, but embodiments of the present disclosure are not limited thereto.

[0322] 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 one or more embodiments, the alkaline earth-metal compound may be selected from BaO, SrO, and CaO, but embodiments of the present disclosure are not limited thereto.

[0323] The rare earth metal compound may be selected from YbF_3, ScF_3, ScO_3, Y_2O_3, Ce_2O_3, GdF_3, and TbF_3. In one or more embodiments, the rare earth metal compound may be selected from YbF_3, ScF_3, TbF_3, YbI_3, ScI_3, and TbI_3, but embodiments of the present disclosure are not limited thereto.

[0324] The alkali metal complex, the alkaline earth-metal complex, and/or 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 a hydroxy quinoline, a hydroxy isoquinoline, a hydroxy benzoquinoline, a hydroxy acridine, a hydroxy phenanthridine, a hydroxy phenyloxazole, a hydroxy phenylthiazole, a hydroxy phenyloxadiazole, a hydroxy phenylthiadiazole, a hydroxy phenylpyridine, a hydroxy phenylbenzimidazole, a hydroxy phenylbenzothiazole, a bipyridine, phenanthroline, and a cyclopentadiene, but embodiments of the present disclosure are not limited thereto.

[0325] The electron injection layer may include (e.g., 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.

[0326] A thickness of the electron injection layer may be 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.

Second Electrode **190**

[0327] The second electrode **190** may be on the organic layer **150** having the above-described structure. The second electrode **190** may be a cathode that is an electron injection electrode, and in this regard, a material for forming the second electrode **190** may be a material having a low work function, such as a metal, an alloy, an electrically conductive compound, or a combination thereof.

[0328] The second electrode **190** may include at least one selected from lithium (Li), silver (Si), magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca),

magnesium-indium (Mg—In), magnesium-silver (Mg—Ag), ITO, and IZO, but embodiments of the present disclosure are not limited thereto. The second electrode **190** may be a transmissive electrode, a semi-transmissive electrode, or a reflective electrode.

[0329] The second electrode **190** may have a single-layered structure, or a multi-layered structure including two or more layers.

Description of FIGS. **2** to **4**

[0330] The organic light-emitting device **20** of FIG. **2** includes a first capping layer **210**, a first electrode **110**, an organic layer **150**, and a second electrode **190** sequentially stacked in this stated order. The organic light-emitting device **30** of FIG. **3** includes a first electrode **110**, an organic layer **150**, a second electrode **190**, and a second capping layer **220** sequentially stacked in this stated order. The organic light-emitting device **40** of FIG. **4** includes a first capping layer **210**, a first electrode **110**, an organic layer **150**, a second electrode **190**, and a second capping layer **220** sequentially stacked in this stated order.

[0331] Regarding FIGS. **2** to **4**, the first electrode **110**, the organic layer **150**, and the second electrode **190** may be understood by referring to the descriptions presented in connection with FIG. **1**.

[0332] In the organic layer **150** of each of the organic light-emitting devices **20** and **40**, light generated in an emission layer may pass through the first electrode **110**, which is a semi-transmissive electrode or a transmissive electrode, and the first capping layer **210** toward the outside, and in the organic layer **150** of each of the organic light-emitting devices **30** and **40**, light generated in an emission layer may pass through the second electrode **190**, which is a semi-transmissive electrode or a transmissive electrode, and the second capping layer **220** toward the outside.

[0333] The first capping layer **210** and the second capping layer **220** may increase the external luminescent efficiency of the device according to the principle of constructive interference.

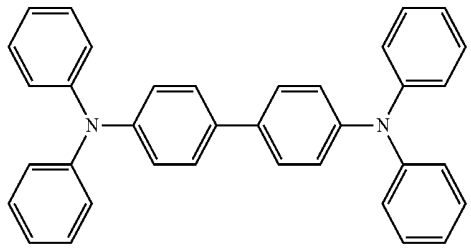
[0334] The first capping layer **210** and the second capping layer **220** may each independently be an organic capping layer including an organic material, an inorganic capping layer including an inorganic material, or a composite capping layer including an organic material and an inorganic material.

[0335] At least one selected from the first capping layer **210** and the second capping layer **220** may each independently include at least one material selected from carbocyclic compounds, heterocyclic compounds, amine-based compounds, porphyrin derivatives, phthalocyanine derivatives, a naphthalocyanine derivatives, alkali metal complexes, and alkaline earth-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 oxygen (O), nitrogen (N), sulfur (S), selenium (Se), silicon (Si), fluorine (F), chlorine (Cl), bromine (Br), and iodine (I). In one or more embodiments, at least one selected from the first capping layer **210** and the second capping layer **220** may each independently include an amine-based compound.

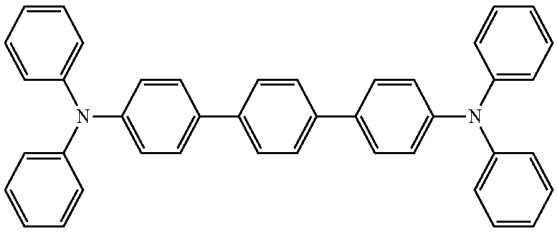
[0336] In one or more embodiments, at least one selected from the first capping layer **210** and the second capping layer **220** may each independently include the compound represented by Formula 201 or the compound represented by Formula 202.

[0337] In one or more embodiments, at least one selected from the first capping layer **210** and the second capping layer **220** may each independently include a compound selected from Compounds HT28 to HT33 and Compounds CP1 to CP5, but embodiments of the present disclosure are not limited thereto.

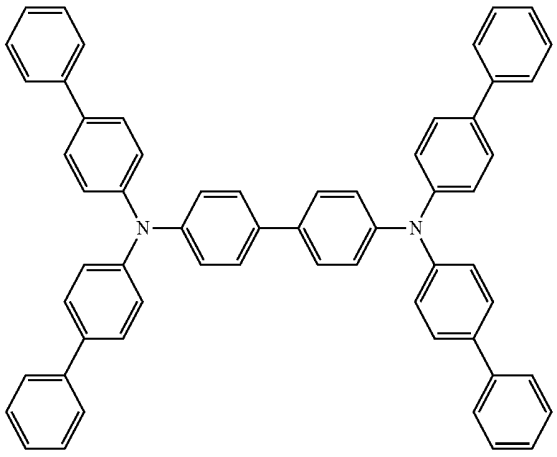
CP1



CP2



CP3



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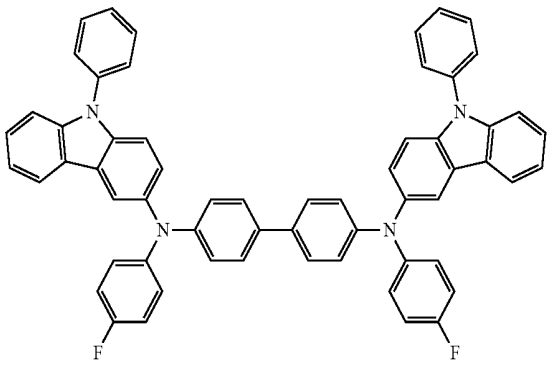

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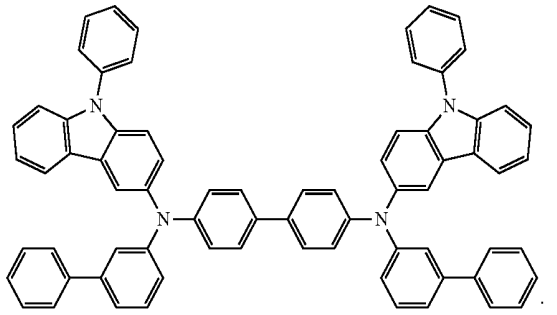
CP5



[0338] Hereinbefore, the organic light-emitting device according to an embodiment of the present disclosure has been described in connection with FIGS. **1-4**. However, embodiments of the present disclosure are not limited thereto.

[0339] Layers constituting the hole transport region, an emission layer, and layers constituting the electron transport region may each independently 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.

[0340] When each of the layers constituting the hole transport region, the emission layer, and each of the layers constituting the electron transport region are formed by vacuum deposition, the vacuum deposition may be performed at a deposition temperature of about 100° C. to about 500° C., about 10^{-8} torr to about 10^{-3} torr, and/or about 0.01 Å/sec to about 100 Å/sec, depending on the material to be included in a layer to be formed, and the structure of a layer to be formed.

[0341] When the layers constituting the hole transport region, the emission layer, and the layers constituting the electron transport region are formed by spin coating, the spin coating may be performed at a coating speed of about 2,000 rpm to about 5,000 rpm and/or at a heat treatment temperature of about 80° C. to about 200° C., depending on the material to be included in a layer and the structure of each layer to be formed.

General Definitions of Some of the Substituents

[0342] The term "C_1-C_{60} alkyl group" as used herein may refer to a linear or branched saturated aliphatic hydrocarbon monovalent group having 1 to 60 carbon atoms, and non-limiting examples thereof may include a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, a pentyl group, an isoamyl group, and a hexyl group. The term "C_1-C_{60} alkylene group" as used herein may refer to a divalent group having substantially the same structure as the C_1-C_{60} alkyl group.

[0343] The term "C_2-C_{60} alkenyl group" as used herein may refer to a hydrocarbon group formed by substituting at least one carbon-carbon double bond in the middle or at the terminus of the C_2-C_{60} alkyl group, and non-limiting examples thereof may include an ethenyl group, a propenyl group, and a butenyl group. The term "C_2-C_{60} alkenylene group" as used herein may refer to a divalent group having substantially the same structure as the C_2-C_{60} alkenyl group.

[0344] The term "C_2-C_{60} alkynyl group" as used herein may refer to a hydrocarbon group formed by substituting at least one carbon-carbon triple bond in the middle or at the terminus of the C_2-C_{60} alkyl group, and non-limiting examples thereof may include an ethynyl group, and a propynyl group. The term "C_2-C_{60} alkynylene group" as used herein may refer to a divalent group having substantially the same structure as the C_2-C_{60} alkynyl group.

[0345] The term "C_1-C_{60} alkoxy group" as used herein may refer to a monovalent group represented by —OA_{101} (wherein A_{101} is a C_1-C_{60} alkyl group), and non-limiting examples thereof may include a methoxy group, an ethoxy group, and an isopropyloxy group.

[0346] The term "C_3-C_{10} cycloalkyl group" as used herein may refer to a monovalent saturated hydrocarbon monocyclic group having 3 to 10 carbon atoms, and non-limiting examples thereof may include a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. The term "C_3-C_{10} cycloalkylene group" as used herein may refer to a divalent group having substantially the same structure as the C_3-C_{10} cycloalkyl group.

[0347] The term "C_1-C_{10} heterocycloalkyl group" as used herein may refer to a monovalent saturated monocyclic group having at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom and 1 to 10 carbon atoms, and non-limiting examples thereof may include a 1,2,3,4-oxatriazolidinyl group, a tetrahydrofuranyl group, a tetrahydrothiophenyl group. The term "C_1-C_{10} heterocycloalkylene group" as used herein may refer to a divalent group having substantially the same structure as the C_1-C_{10} heterocycloalkyl group.

[0348] The term "C_3-C_{10} cycloalkenyl group" as used herein may refer to a monovalent monocyclic group that has 3 to 10 carbon atoms and at least one carbon-carbon double bond in the ring thereof and no aromaticity (e.g., the C_3-C_{10} cycloalkenyl group is not aromatic), and non-limiting examples thereof may include a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. The term "C_3-C_{10} cycloalkenylene group" as used herein may refer to a divalent group having substantially the same structure as the C_3-C_{10} cycloalkenyl group.

[0349] The term "C_1-C_{10} heterocycloalkenyl group" as used herein may refer to a monovalent monocyclic group having at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, 1 to 10 carbon atoms, and at least one double bond in its ring. Non-limiting examples of the C_1-C_{10} heterocycloalkenyl group may include a 4,5-dihydro-1,2,3,4-oxatriazolyl group, a 2,3-dihydrofuranyl group, and a 2,3-dihydrothiophenyl group. The term "C_1-C_{10} heterocycloalkenylene group" as used herein may refer to a divalent group having substantially the same structure as the C_1-C_{10} heterocycloalkenyl group.

[0350] The term "C_6-C_{60} aryl group" as used herein may refer to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms, and the term "C_6-C_{60} arylene group" as used herein may refer to a divalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms. Non-limiting examples of the C_6-C_{60} aryl group may include a phenyl group, a naphthyl group, an anthracenyl group, a phenanthrenyl group, a pyrenyl group, and a chrysenyl group. When the C_6-C_{60} aryl group and the C_6-C_{60} arylene group each include two or more rings, the rings may be fused (e.g., condensed) to each other.

[0351] The term "C_1-C_{60} heteroaryl group" as used herein may refer to a monovalent group having a heterocyclic aromatic system that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, in addition to 1 to 60 carbon atoms. The term "C_1-C_{60} heteroarylene group" as used herein may refer to a divalent group having a heterocyclic aromatic system that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, in addition to 1 to 60 carbon atoms. Non-limiting examples of the C_1-C_{60} heteroaryl group may 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 fused (e.g., condensed) to each other.

[0352] The term "C_6-C_{60} aryloxy group" as used herein may refer to —OA_{102} (wherein A_{102} is a C_6-C_{60} aryl group), and a C_6-C_{60} arylthio group used herein may refer to —SA_{103} (wherein A_{103} is a C_6-C_{60} aryl group).

[0353] The term "monovalent non-aromatic condensed polycyclic group" as used herein may refer 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 (e.g., the entire molecule is not aromatic). A non-limiting example of the monovalent non-aromatic condensed polycyclic group may be a fluorenyl group. The term "divalent non-aromatic condensed polycyclic group" as used herein may refer to a divalent group having substantially the same structure as the monovalent non-aromatic condensed polycyclic group.

[0354] The term "monovalent non-aromatic condensed heteropolycyclic group" as used herein may refer 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 (e.g., the entire molecule is not aromatic). A non-limiting example of the monovalent non-aromatic condensed heteropolycyclic group may be a carbazolyl group. The term "divalent non-aromatic condensed heteropolycyclic group" as used herein may refer to a divalent group having substantially the same structure as the monovalent non-aromatic condensed heteropolycyclic group.

[0355] The term "C_5-C_{60} carbocyclic group" as used herein may refer 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.

[0356] The term "C_1-C_{60} heterocyclic group" as used herein may refer to a group having substantially 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 1 to 60).

[0357] At least one substituent of the substituted C_5-C_{60} carbocyclic group, the substituted C_1-C_{60} heterocyclic group, the substituted C_3-C_{10} cycloalkylene group, the substituted C_1-C_{10} heterocycloalkylene group, the substituted C_3-C_{10} cycloalkenylene group, the substituted C_1-C_{10} heterocycloalkenylene group, the substituted C_6-C_{60} arylene group, the substituted C_1-C_{60} heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, the substituted divalent non-aromatic condensed heteropolycyclic group, the substituted C_1-C_{60} alkyl group, the substituted C_2-C_{60} alkenyl group, the substituted C_2-C_{60} alkynyl group, the substituted C_1-C_{60} alkoxy group, the substituted C_3-C_{10} cycloalkyl group, the substituted C_1-C_{10} heterocycloalkyl group, the substituted C_3-C_{10} cycloalkenyl group, the substituted C_1-C_{10} heterocycloalkenyl group, the substituted C_6-C_{60} aryl group, the substituted C_6-C_{60} aryloxy group, the substituted C_6-C_{60} arylthio group, the substituted C_1-C_{60} heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from:

[0358] 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;

[0359] 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, —$Si(Q_{11})(Q_{12})(Q_{13})$, —$N(Q_{11})(Q_{12})$, —$C(=O)(Q_{11})$, —$S(=O)_2(Q_{11})$ and —$P(=O)(Q_{11})(Q_{12})$;

[0360] 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;

[0361] 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}); and

[0362] —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)(O_{31})(Q_{32}), and

[0363] Q_{11} Q_{13},to Q_{23},and $Q_{31}$to may each independentlybeselected to Q_{21} 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.

[0364] The term "Ph", as used herein, may refer to a phenyl group; the term "Me", as used herein, may refer to a methyl group; the term "Et", as used herein, may refer to an ethyl group; the terms "ter-Bu" or "But", as used herein, may refer to a tert-butyl group; and the term "OMe" as used herein may refer to a methoxy group.

[0365] The term "biphenyl group" as used herein may refer 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 (specifically, a phenyl group) as a substituent.

[0366] The term "terphenyl group" as used herein may refer 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 (specifically, a phenyl group substituted with a phenyl group).

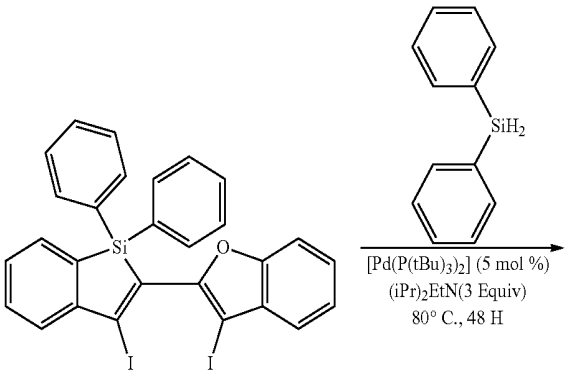
[0367] * and *' used herein, unless defined otherwise, each refer to a binding site to a neighboring atom in a corresponding formula.

[0368] Hereinafter, a compound according to embodiments of the present disclosure and an organic light-emitting device according to embodiments of the present disclosure will be described in more detail with reference to Synthesis Examples and Examples. The wording "B was used instead of A" used in describing Synthesis Examples indicates that an identical molar equivalent of B was used in place of A.

SYNTHESIS EXAMPLE 1

Synthesis of Compound 1

[0369]



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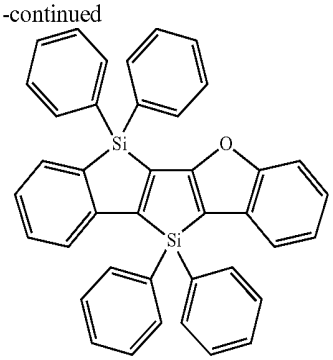


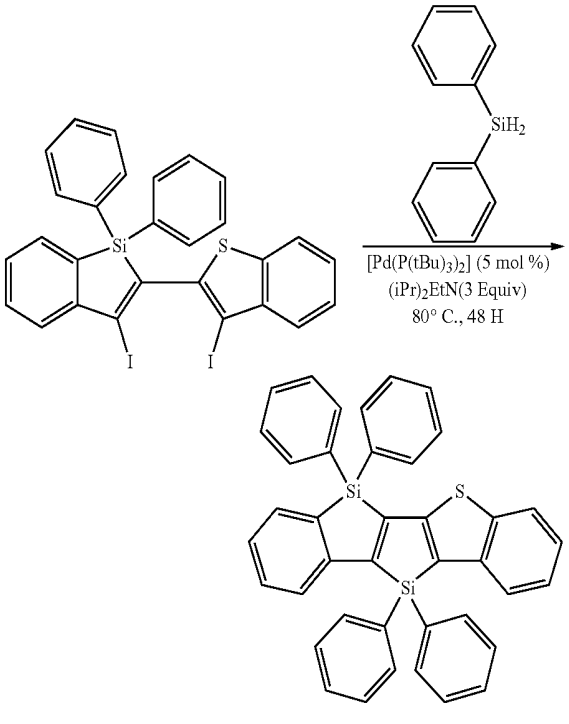
[0370] 3 g (0.0046 mol) of 3-iodo-2-(3-iodo-1,1-diphenyl-1H-benzo[b]silol-2-yl)benzofuran and 0.85 g (0.0046 mol) of diphenylsilane were added to a 3-neck flask (250 mL) and dissolved in 50 mL of N,N-diisopropylethylamine and 150 mL of THF, and oxygen was removed therefrom while stirring the resultant mixture. Then, nitrogen gas was substituted, 0.2 g of bis(tri-tert-butylphosphine)palladium(0) as a catalyst was added thereto, and the reaction was refluxed at a temperature of 80° C. for 48 hours. After the reaction was terminated with water, extraction was performed thereon three times using methylene chloride (MC), and a solvent was removed therefrom. Column chromatography was performed on the result obtained therefrom using a solvent system of ethyl acetate (EA): hexane (Hex) (1:10) to obtain 1.33 g (50%) of Compound 1. H-NMR data of Compound 1 is as follows:

[0371] H-NMR($CDCl_3$): 7.84 (1H, d), 7.50 (1H, d), 7.46-7.20 (26H, m).

SYNTHESIS EXAMPLE 2

Synthesis of Compound 2

[0372]



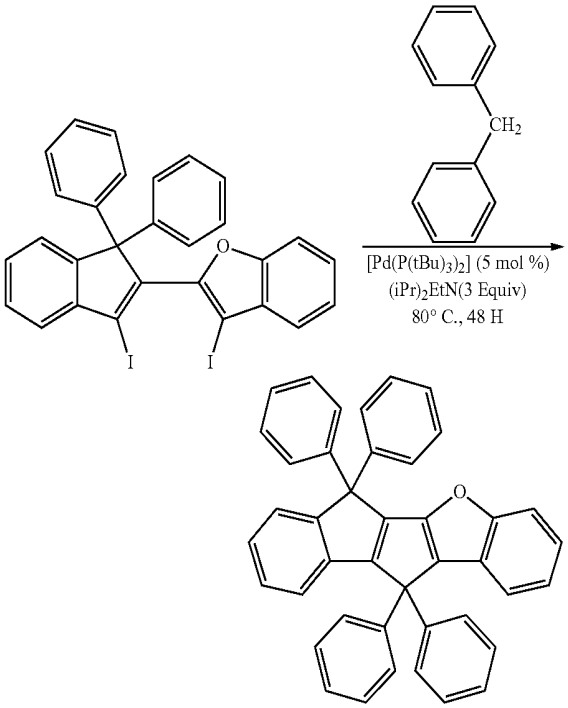
[0373] 3 g (0.0045 mol) of 3-iodo-2-(3-iodo-1,1-diphenyl-1H-benzo[b]silol-2-yl)benzo[b]thiophene and 0.83 g (0.0045 mol) of diphenylsilane were added to a 3-neck flask (250 mL) and dissolved in 50 mL of N,N-diisopropylethylamine and 150 mL of THF, and oxygen was removed therefrom while stirring the resultant mixture. Then, nitrogen gas was substituted, 0.2 g of bis(tri-tert-butylphosphine) palladium(0) as a catalyst was added thereto, and the reaction was refluxed at a temperature of 80° C. for 48 hours. After the reaction was terminated with water, extraction was performed thereon three times using MC and a solvent was removed therefrom. Column chromatography was performed on the result obtained therefrom using a solvent system of EA:Hex (1:10) to obtain 1.29 g (48%) of Compound 2. H-NMR data of Compound 2 is as follows:

[0374] H-NMR($CDCl_3$): 8.05 (1H, d), 7.93 (1H, d), 7.46-7.25 (26H, m).

SYNTHESIS EXAMPLE 3

Synthesis of Compound 3

[0375]



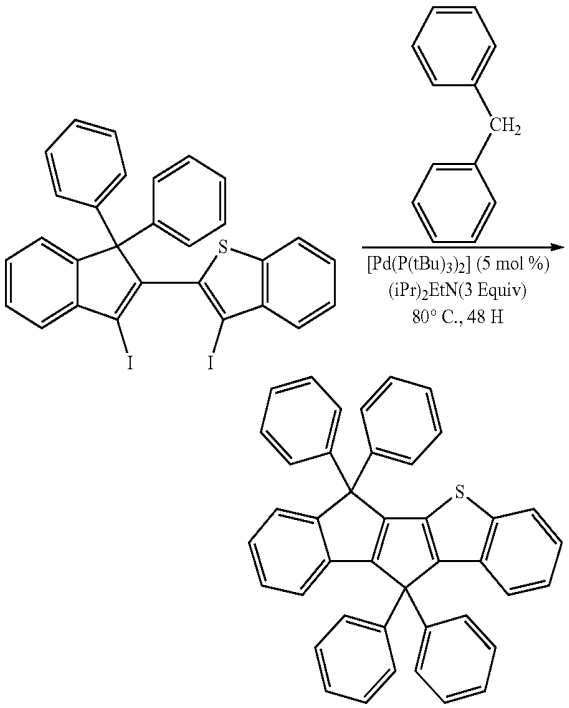
[0376] 3 g (0.0047 mol) of 3-iodo-2-(3-iodo-1,1-diphenyl-1H-inden-2-yl)benzofuran and 0.79 g (0.0047 mol) of diphenylmethane were added to a 3-neck flask (250 mL) and dissolved in 50 mL of N,N-diisopropylethylamine and 150 mL of THF, and oxygen was removed therefrom while stirring the resultant mixture. Then, nitrogen was substituted, 0.2 g of bis(tri-tert-butylphosphine)palladium(0) as a catalyst was added thereto, and the reaction was refluxed at a temperature of 80° C. for 48 hours. After the reaction was terminated with water, extraction was performed thereon three times using MC and a solvent was removed therefrom. Column chromatography was performed on the result obtained therefrom using a solvent system of EA:Hex (1:10) to obtain 1.29 g (50%) of Compound 3. H-NMR data of Compound 3 is as follows:

[0377] H-NMR($CDCl_3$): 7.84 (1H, d), 7.59 (1H, d), 7.46-7.20 (26H, m).

SYNTHESIS EXAMPLE 4

Synthesis of Compound 4

[0378]



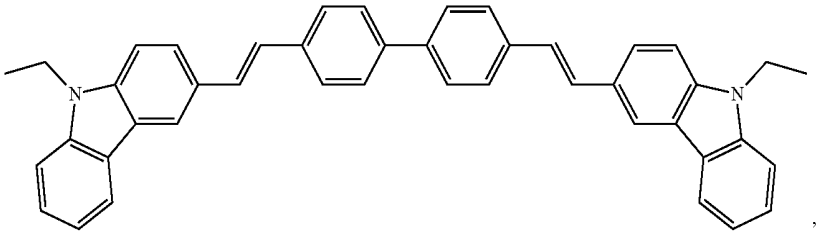
[0379] 3 g (0.0046 mol) of 3-iodo-2-(3-iodo-1,1-diphenyl-1H-inden-2-yl)benzo[b]thiophene and 0.77 g (0.0046 mol) of diphenylmethane were added to a 3-neck flask (250 mL) and dissolved in 50 mL of N,N-diisopropylethylamine and 150 mL of THF, and oxygen was removed therefrom while stirring the resultant mixture. Then, nitrogen was substituted, 0.2 g of bis(tri-tert-butylphosphine)palladium(0) as a catalyst was added thereto, and the reaction was refluxed at a temperature of 80° C. for 48 hours. After the reaction was terminated with water, extraction was performed thereon three times using MC and a solvent was removed therefrom. Column chromatography was performed on the result obtained therefrom using a solvent system of EA:Hex (1:10) to obtain 1.25 g (48%) of Compound 4. H-NMR data of Compound 4 is as follows:

[0380] H-NMR($CDCl_3$): 8.05 (1H, d), 7.90 (1H, d), 7.46-7.25 (26H, m).

[0381] The electrical and optical characteristics of Compounds 1 to 4 (as synthesized according to Synthesis Examples 1 to 4), BCzVBi, and Compounds A and B were evaluated using cyclic voltammetry and UV-PL measurement methods. The results thereof are shown in Table 1.

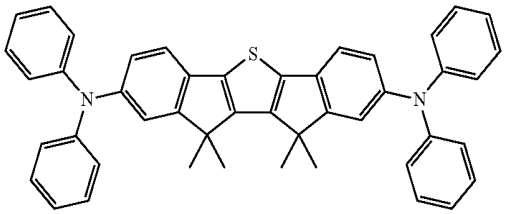
TABLE 1

	HOMO (eV)	LUMO (eV)	E_{T1} (eV)	E_{T2} (eV)	λ_{max} (nm)
Compound 1	−5.8	−2.3	1.53	3.08	457
Compound 2	−5.9	−2.3	1.55	3.11	455
Compound 3	−5.7	−2.1	1.52	3.10	459
Compound 4	−5.8	−2.1	1.55	3.12	460
BCzVBi	−5.5	−2.1	2.06	2.33	461
Compound A	−5.3	−2.0	1.90	2.77	495
Compound B	−5.8	−2.3	2.60	2.87	463

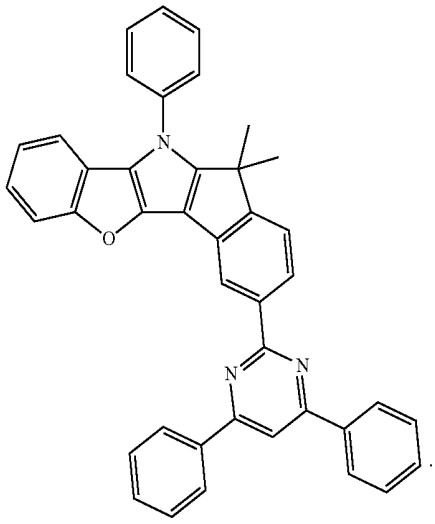


BCzVBi

Compound A



Compound B



EXAMPLE 1

[0382] As a substrate and an anode, a Corning 15 Ω/cm^2 (120 nm) ITO glass substrate was cut to a size of 50 mm×50 mm×0.5 mm, sonicated with acetone, isopropyl alcohol, and deionized water each for 5 minutes, and then cleaned by exposure to ultraviolet rays and ozone for 10 minutes. Then, the ITO glass substrate was provided to a vacuum deposition apparatus.

[0383] HATCN was vacuum-deposited on the anode to form a hole injection layer having a thickness of 100 Å, and TAPC was deposited on the hole injection layer to a thickness of 500 Å to form a hole transport layer having a thickness of 50 nm.

[0384] TCTA was deposited on the hole transport layer to form an auxiliary layer having a thickness of 50 Å.

[0385] Then, mADN (host) and Compound 1 (dopant) were co-deposited on the auxiliary layer at a weight ratio of 95:5 to form an emission layer having a thickness of 300 Å.

[0386] Then, TPBI and LiQ were co-deposited on the emission layer at a ratio of 50:50 to form an electron transport layer having a thickness of 360 Å, LiQ was deposited on the electron transport layer to form an electron injection layer having a thickness of 10 Å, and Mg and Ag were co-deposited on the electron injection layer to form a cathode having a thickness of 1,000 Å, thereby completing the manufacture of an organic light-emitting device.

EXAMPLE 2

[0387] An organic light-emitting device was manufactured in substantially the same manner as in Example 1, except that Compound 2 was used instead of Compound 1.

EXAMPLE 3

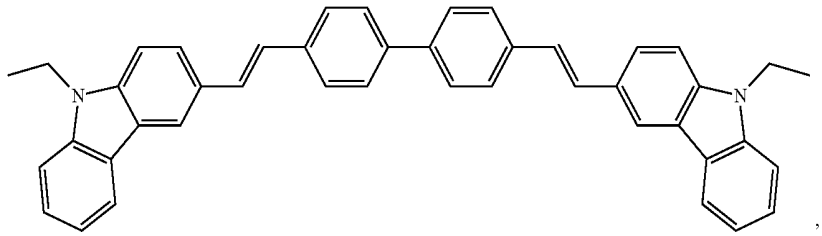
[0388] An organic light-emitting device was manufactured in substantially the same manner as in Example 1, except that Compound 3 was used instead of Compound 1.

EXAMPLE 4

[0389] An organic light-emitting device was manufactured in substantially the same manner as in Example 1, except that Compound 4 was used instead of Compound 1.

COMPARATIVE EXAMPLE 1

[0390] An organic light-emitting device was manufactured in substantially the same manner as in Example 1, except that BCzVBi was used instead of Compound 1.

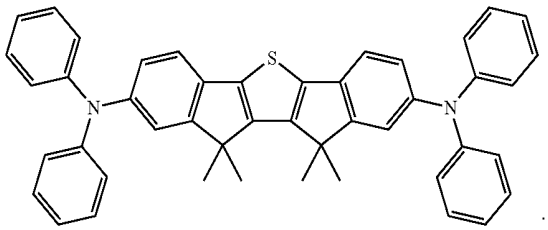


BCzVBi

COMPARATIVE EXAMPLE 2

[0391] An organic light-emitting device was manufactured in substantially the same manner as in Example 1, except that Compound A was used instead of Compound 1.

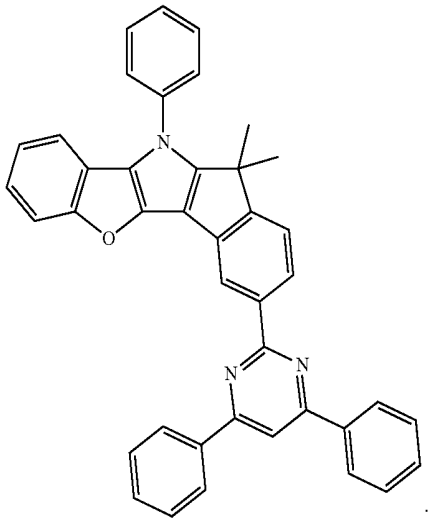
Compound A



COMPARATIVE EXAMPLE 3

[0392] An organic light-emitting device was manufactured in substantially the same manner as in Example 1, except that Compound B was used instead of Compound 1.

Compound B



[0393] The driving voltage, luminance, efficiency, and delayed fluorescence component ratio of the organic light-emitting devices manufactured according to Examples 1 to 4 and Comparative Examples 1 to 3 were evaluated using a Keithley SMU 236 and PR650 Spectroscan Source Measurement Unit (manufactured by Photo Research Inc., Syracuse, N.Y.), and the results thereof are shown in Table 2. The lifespan (T90) indicates an amount of time that lapsed when luminance was 90% of initial luminance (100%).

TABLE 2

	Host (A)	Dopant (B)	Driving voltage (V)	Brightness (cd/m^2)	Efficiency (cd/A)	Lifespan (T90) (hr)	Delayed fluorescence component
Example 1	mADN	Compound 1	3.88	1000	12.2	85	52%
Example 2	mADN	Compound 2	3.82	1000	13.3	95	58%
Example 3	mADN	Compound 3	4.12	1000	10.3	53	43%
Example 4	mADN	Compound 4	4.08	1000	11.2	48	41%
Comparative Example 1	mADN	BCzVBi	4.28	1000	8.5	5	23%
Comparative Example 2	mADN	Compound A	4.01	1000	4.8	10	20%
Comparative Example 3	mADN	Compound B	4.45	1000	5.8	5	18%

[0394] Referring to Table 2, it is confirmed that the organic light-emitting devices of Examples 1 to 4 had a low driving voltage, high efficiency, a long lifespan, and a large amount of a delayed fluorescence component, as compared with those of the organic light-emitting devices of Comparative Examples 1 to 3.

[0395] An organic light-emitting device including the condensed cyclic compound may have a low driving voltage, high efficiency, a long lifespan, and a large amount of a delayed fluorescence component.

[0396] As used herein, the terms "use", "using", and "used" may be considered synonymous with the terms "utilize", "utilizing", and "utilized", respectively. Further, the use of "may" when describing embodiments of the present disclosure may refer to "one or more embodiments of the present disclosure".

[0397] As used herein, the terms "substantially", "about", and similar terms are used as terms of approximation and not as terms of degree, and are intended to account for the inherent deviations in measured or calculated values that would be recognized by those of ordinary skill in the art.

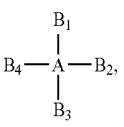
[0398] Also, any numerical range recited herein is intended to include all sub-ranges of the same numerical precision subsumed within the recited range. For example, a range of "1.0 to 10.0" is intended to include all subranges between (and including) the recited minimum value of 1.0 and the recited maximum value of 10.0, that is, having a minimum value equal to or greater than 1.0 and a maximum value equal to or less than 10.0 such as, for example, 2.4 to 7.6. Any maximum numerical limitation recited herein is intended to include all lower numerical limitations subsumed therein and any minimum numerical limitation recited in this specification is intended to include all higher numerical limitations subsumed therein. Accordingly, Applicant reserves the right to amend this specification, including the claims, to expressly recite any sub-range subsumed within the ranges expressly recited herein.

[0399] It should be understood that embodiments described herein should be considered in a descriptive sense only and not for purposes of limitation. Descriptions of features or aspects within each embodiment should typically be considered as available for other similar features or aspects in other embodiments.

[0400] While one or more embodiments have been described with reference to the drawings, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope as defined by the following claims and equivalents thereof.

What is claimed is:

1. A condensed cyclic compound represented by Formula 1:



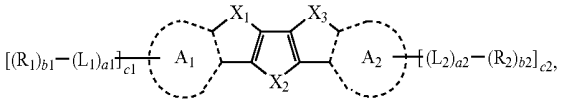
Formula 1

wherein, in Formula 1,

A is a moiety represented by Formula 1-1, and

B_1 to B_4 are each independently selected from a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group:

Formula 1-1



wherein, in Formula 1-1,

X_1 is a carbon atom (C) linked to B_1 and B_2 or a silicon atom (Si) linked to B_1 and B_2,

X_2 is a carbon atom linked to B_3 and B_4 or a silicon atom linked to B_3 and B_4,

X_3 iS O or S,

A_1 and A_2 are each independently a benzene group, a pyridine group, a pyrimidine group, a pyridazine group, or a pyrazine group,

L_1 and L_2 are each independently a substituted or unsubstituted C_5-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group,

a1 and a2 are each independently an integer from 0 to 5,

R_1 and R_2 are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_2-C_{60} alkynyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —$Si(Q_1)(Q_2)(Q_3)$, —$B(Q_1)(Q_2)$, —$C(=O)(Q_1)$, —$N(Q_1)(Q_2)$, —$P(=O)(Q_1)(Q_2)$, —$P(=O)_2(Q_1)$, —$P(=S)(Q_1)(Q_2)$, —$P(=S)_2(Q_1)$, —$S(=O)(Q_1)(Q_2)$, and —$S(=O)_2(Q_1)(Q_2)$,

b1 and b2 are each independently an integer from 1 to 10,

c1 and c2 are each independently 1, 2, 3, or 4,

at least one substituent of the substituted C_5-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, and a monovalent non-aromatic condensed heteropolycyclic group;

a C_3-C_{10} cycloalkyl group, a C_i-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 $—P(=O)(Q_{21})(Q_{22})$; 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 $—P(=O)(Q_{31})(Q_{32})$, and

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_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.

2. The condensed cyclic compound of claim **1**, wherein:

X_1 is a carbon atom linked to B_1 and B_2, and X_2 is a carbon atom linked to B_3 and B_4; or

X_1 is a silicon atom linked to B_1 and B_2, and X_2 is a silicon atom linked to B_3 and B_4.

3. The condensed cyclic compound of claim **1**, wherein A_1 and A_2 are each a benzene group.

4. The condensed cyclic compound of claim **1**, wherein B_1 to B_4 are each independently selected from 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.

5. The condensed cyclic compound of claim **1**, wherein:

B_1 to B_4 are each independently selected from:

a phenyl group and a pyridinyl group; and

a phenyl group and a pyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a methyl group, an ethyl group, a propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an isoamyl group, a hexyl group, a phenyl group, and $—Si(Q_{31})(Q_{32})(Q_{32})$.

6. The condensed cyclic compound of claim **1**, wherein:

B_1 to B_4 in Formula 1 are each independently selected from:

a phenyl group, and a pyridinyl group; and

a phenyl group and a pyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a methyl group, an ethyl group, a propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an isoamyl group, a hexyl group, a phenyl group, and $—Si(Q_{31})(Q_{32})(Q_{32})$, and

R_1 and R_2 in Formula 1-1 are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a methyl group, an ethyl group, a propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an isoamyl group, a hexyl group, a phenyl group, a biphenyl group, and a pyridinyl group.

7. The condensed cyclic compound of claim **1**, wherein:

B_1 to B_4 in Formula 1 are each independently selected from:

a phenyl group, and a pyridinyl group; and

a phenyl group and a pyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a methyl group, an ethyl group, a propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an isoamyl group, a hexyl group, a phenyl group, and $—Si(Q_{31})(Q_{32})(Q_{32})$, and

A_1 and A_2 in Formula 1-1 are each a benzene group.

8. The condensed cyclic compound of claim **1**, wherein, in Formula 1,

a dihedral angle between a plane P1 including A and a plane P2 including B_n is 60° or more, and

n is 1, 2, 3, or 4.

9. The condensed cyclic compound of claim **1**, wherein:

the condensed cyclic compound satisfies Equation 1:

$$E_{S1}>2E_{T1}>E_{T2}, \quad \text{Equation 1}$$

wherein, in Equation 1,

E_{S1} is the first singlet energy level of the condensed cyclic compound,

E_{T1} is the first triplet energy level of the condensed cyclic compound, and

E_{T2} is the second triplet energy level of the condensed cyclic compound.

10. The condensed cyclic compound of claim **9**, wherein E_{S1} is about 2.7 eV to about 3.0 eV.

11. The condensed cyclic compound of claim **9**, wherein E_{T2} is about 2.8 eV to about 3.4 eV.

12. The condensed cyclic compound of claim **1**, wherein the condensed cyclic compound satisfies Equation 2:

$$2E_{AT1}<E_{BT1}, \quad \text{Equation 2}$$

wherein, in Equation 2,

E_{AT1} is the first triplet energy level of A,

E_{BT1} is the first triplet energy level of B_n, and n is 1, 2, 3, or 4.

13. 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,

wherein the organic layer comprises an emission layer and at least one of the condensed cyclic compound of claim **1**.

14. The organic light-emitting device of claim **13**, wherein:

the first electrode is an anode,

the second electrode is a cathode,

the organic layer further comprises 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 comprises a hole injection layer, a hole transport layer, an emission auxiliary layer, an electron blocking layer, or any combination thereof, and

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

15. The organic light-emitting device of claim **13**, wherein the emission layer comprises the condensed cyclic compound.

16. The organic light-emitting device of claim **15**, wherein:

the emission layer further comprises a host, and

an amount of the host in the emission layer is larger than an amount of the condensed cyclic compound.

17. The organic light-emitting device of claim **16**, wherein the condensed cyclic compound is provided to emit delayed fluorescence.

18. The organic light-emitting device of claim **16**, wherein an amount of the condensed cyclic compound in the emission layer is about 0.01 parts by weight to about 30 parts by weight based on 100 parts by weight of the host.

19. The organic light-emitting device of claim **16**, wherein:

the host comprises a compound represented by Formula 301:

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

wherein, in Formula 301,

Ar_{301} is a substituted or unsubstituted C_5-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group,

xb11 is 1, 2, or 3,

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,

xb1 is an integer from 0 to 5,

R_{301} is selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_2-C_{60} alkynyl group, 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 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 —$P(=O)(Q_{301})(Q_{302})$,

xb21 is an integer from 1 to 5, and

Q_{301} to Q_{303} are each independently selected from a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

20. The organic light-emitting device of claim **13**, wherein the emission layer comprises the condensed cyclic compound, and light having a maximum emission wavelength of about 420 nm to about 470 nm is emitted from the emission layer.

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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	US20190173027A1	公开(公告)日	2019-06-06
申请号	US16/121365	申请日	2018-09-04
[标]申请(专利权)人(译)	三星显示有限公司		
申请(专利权)人(译)	三星DISPLAY CO.，LTD.		
当前申请(专利权)人(译)	三星DISPLAY CO.，LTD.		
[标]发明人	KIM SEULONG SHIN DAEYUP		
发明人	KIM, SEULONG SHIN, DAEYUP		
IPC分类号	H01L51/00 C09K11/06		
CPC分类号	H01L51/0094 H01L51/0073 H01L51/0074 H01L51/0072 C09K11/06 H01L51/5012 H01L51/5016 C09K2211/1022 C09K2211/1018 C09K2211/1007 C07D307/77 C07D333/78 C07F7/0816 C09K2211/1088 C09K2211/1092 C09K2211/1096 H01L51/0071 H01L51/5056 H01L51/5072 H01L51/5088 H01L51/5092 H01L51/5096 H01L2251/552		
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外部链接	Espacenet USPTO		

摘要(译)

提供了发射高效延迟荧光的稠合环状化合物。该化合物可以由式1表示，其中A是式1-1表示的部分。在式1-1中，X 1 可以是与B 1 和B 2 连接的碳或硅原子，并且X 2 可以是与B 3 和B 4 连接的碳或硅原子。 当式1表示的化合物满足E S1 & #x3c; 2E T1 & #x3c; E T2 （其中E S1 ）是第一个单重态能级，E T1 是第一个三重态能级，E T2 是浓缩环状化合物的第二个三重态能级，在通过与三重态能量状态中的相邻分子的相互作用将稠合环状化合物从三重态向上转换为单重态期间，能量转变到第二三重态可能是不利的。