



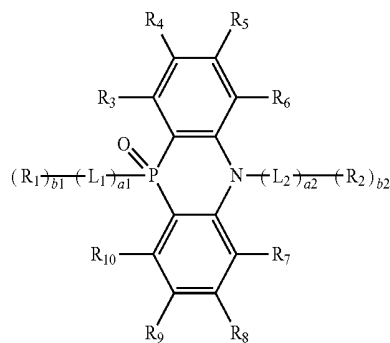
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KIM et al.(10) **Pub. No.: US 2018/0240980 A1**(43) **Pub. Date: Aug. 23, 2018**(54) **HETEROCYCLIC COMPOUND AND
ORGANIC LIGHT-EMITTING DEVICE
INCLUDING THE SAME**(71) Applicants: **Samsung Display Co., Ltd.**, Yongin-si
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(2013.01)(57) **ABSTRACT**

A heterocyclic compound and an organic light-emitting device including the same are provided. The heterocyclic compound may be represented by Formula 1. The substituents and variables of Formula 1 may be as defined in the present disclosure. The organic light-emitting device including the heterocyclic compound represented by Formula 1 may have a low driving voltage, high current density, and high efficiency.



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HETEROCYCLIC 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. 10-2017-0021727, filed on Feb. 17, 2017, in the Korean Intellectual Property Office, the entire content of which is incorporated herein by reference.

BACKGROUND

1. Field

[0002] One or more embodiments relate to a heterocyclic 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 also have wide viewing angles, high contrast ratios, short response times, and excellent characteristics in terms of brightness, driving voltage, and response speed, as compared to other devices in the art.

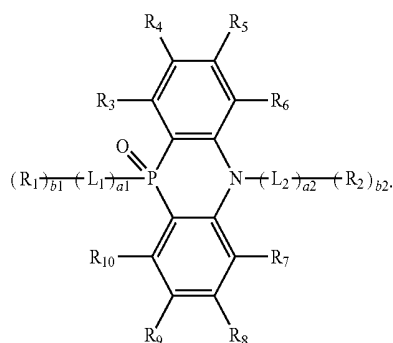
[0004] An example of such organic light-emitting devices may include a first electrode disposed on a substrate, and a hole transport region, an emission layer, an electron transport region, and a second electrode, which are sequentially disposed on the first electrode. Holes provided from the first electrode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

SUMMARY

[0005] One or more embodiments include a heterocyclic 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] According to one or more embodiments, a heterocyclic compound is represented by Formula 1:



Formula 1

[0008] In Formula 1,

[0009] 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,

[0010] R_1 and R_3 to R_{10} may each independently be selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, $-Si(Q_{31})(Q_{32})(Q_{33})$, $P(=O)(Q_{31})(Q_{32})$, 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, a biphenyl group, and a terphenyl group,

[0011] R_2 may be (i) a C_6 - C_{60} aryl group substituted with at least one electron withdrawing group or (ii) a substituted or unsubstituted π electron-depleted nitrogen-containing ring group,

[0012] a_1 may be an integer from 0 to 5,

[0013] a_2 may be an integer from 0 to 5,

[0014] b_1 may be an integer from 0 to 5,

[0015] b_2 may be an integer from 1 to 5,

[0016] 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, the substituted monovalent non-aromatic condensed heteropolycyclic group, and the substituted π electron-depleted nitrogen-containing ring group may be selected from:

[0017] 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;

[0018] 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, and a monovalent non-aromatic condensed heteropolycyclic group;

[0019] a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group;

[0020] a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group; and

[0021] —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂), and

[0022] Q₃₁ to Q₃₃ may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryl group substituted with a C₁-C₆₀ alkyl group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

[0023] According to one or more embodiments, an organic light-emitting device includes: a first electrode; a second electrode facing the first electrode; and an organic layer between the first electrode and the second electrode, the organic layer including an emission layer and at least one of the heterocyclic compound described above.

BRIEF DESCRIPTION OF THE DRAWING

[0024] 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 drawing which is a schematic view of an organic light-emitting device according to an embodiment.

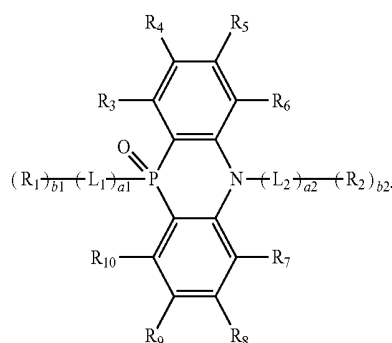
DETAILED DESCRIPTION

[0025] Reference will now be made in more detail to embodiments, examples of which are illustrated in the accompanying drawing. In this regard, the present embodiments may have different forms and should not be construed as being limited to the descriptions set forth herein. Accordingly, the embodiments are merely described below, by

referring to the drawing, to explain aspects of the present description. As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items. Expressions such as “at least one of,” when preceding a list of elements, modify the entire list of elements and do not modify the individual elements of the list.

[0026] A heterocyclic compound according to an embodiment may be represented by Formula 1:

Formula 1



[0027] L₁ and L₂ in Formula 1 may each independently be a substituted or unsubstituted C₅-C₆₀ carbocyclic group or a substituted or unsubstituted C₁-C₆₀ heterocyclic group.

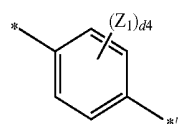
[0028] In one embodiment, L₁ and L₂ may each independently be selected from:

[0029] a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a naphthofluorene group, a pyridine group, a pyrimidine group, a pyridazine group, a triazine group, a pyrrole group, a thiophene group, a furan group, an imidazole group, a pyrazole group, an oxazole group, an isoxazole group, a thiazole group, an isoxazole group, a triazole group, a carbazole group, a dibenzofuran group, a benzonaphthofuran group, a dibenzothiophene group, a benzocarbazole group, and a dibenzocarbazole group; and

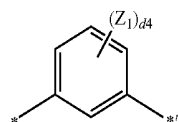
[0030] a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a naphthofluorene group, a pyridine group, a pyrimidine group, a pyridazine group, a triazine group, a pyrrole group, a thiophene group, a furan group, an imidazole group, a pyrazole group, an oxazole group, an isoxazole group, a thiazole group, an isoxazole group, a triazole group, a carbazole group, a dibenzofuran group, a benzonaphthofuran 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 amidino group, a hydrazino group, a hydrazono group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a carbazolyl group, a dibenzofuranyl group, a benzonaphthofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group.

[0031] In one or more embodiments, L_1 may be selected from groups represented by Formulae 3-1 to 3-15:

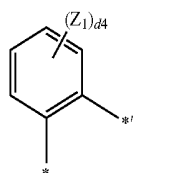
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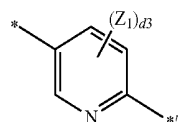
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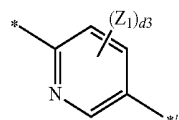
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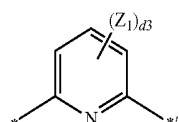
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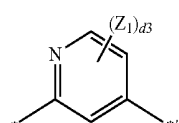
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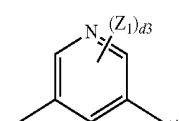
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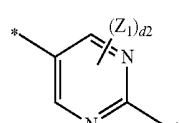
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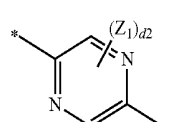
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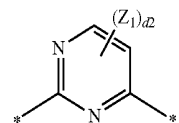
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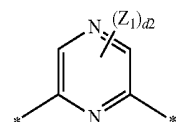
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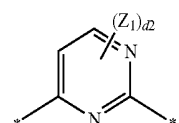
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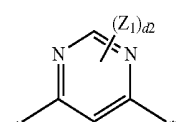
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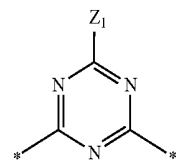
3-12



3-13



3-14



3-15

[0032] In Formulae 3-1 to 3-15,

[0033] Z_1 may be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, 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 pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a triazinyl group, a benzimidazolyl group, a phenanthrolinyl group, a biphenyl group, and a terphenyl group,

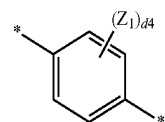
[0034] d_2 may be an integer from 0 to 2,

[0035] d_3 may be an integer from 0 to 3,

[0036] d_4 may be an integer from 0 to 4, and

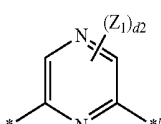
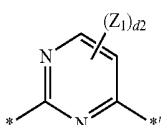
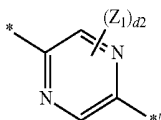
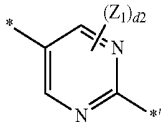
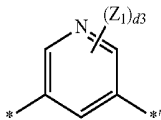
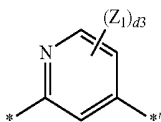
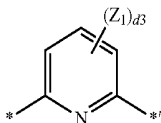
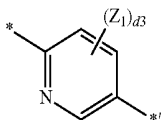
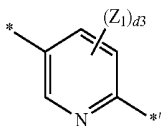
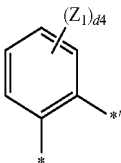
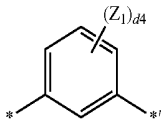
[0037] * and *' each indicate a binding site to a neighboring atom.

[0038] In one embodiment, L_2 may be selected from groups represented by Formulae 3-1 to 3-58:

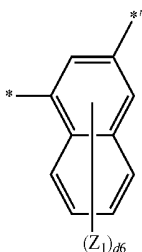
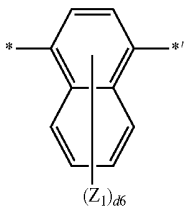
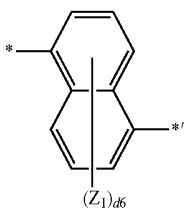
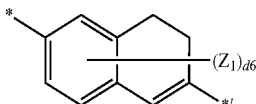
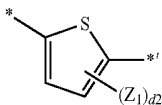
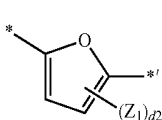
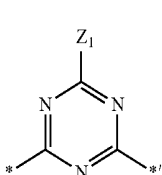
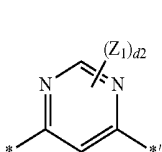
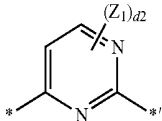


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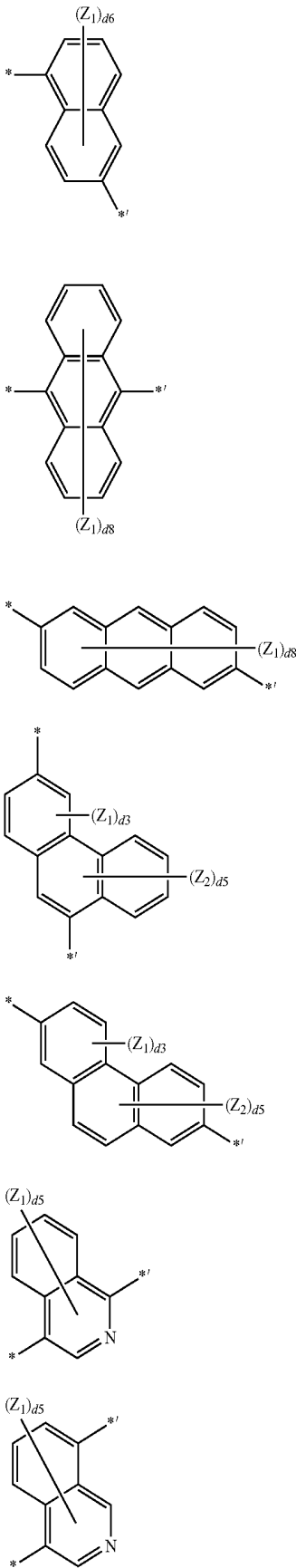
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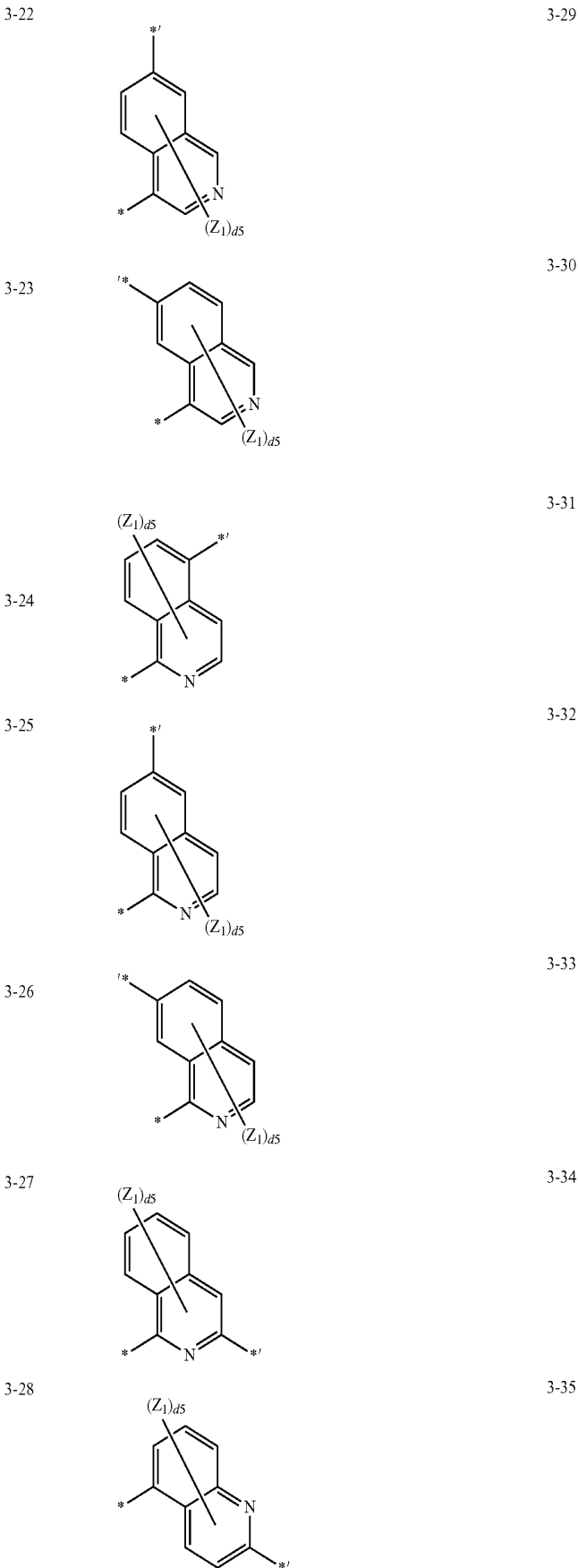
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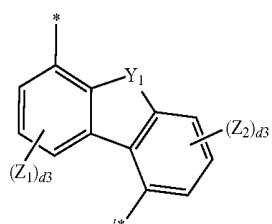
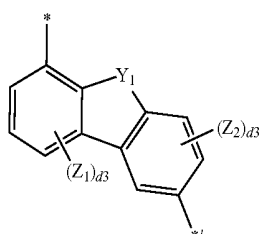
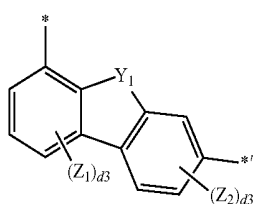
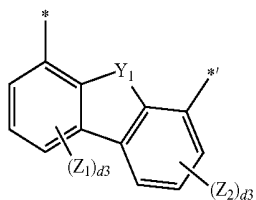
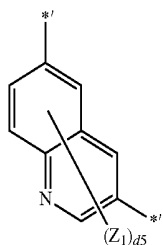
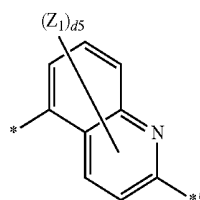
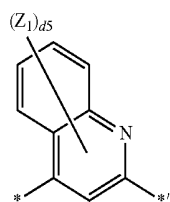
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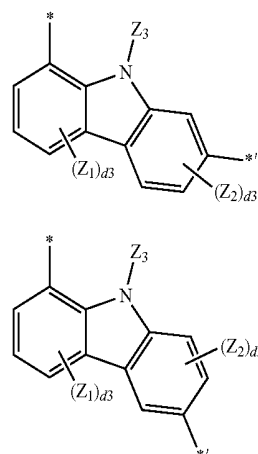
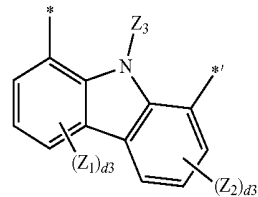
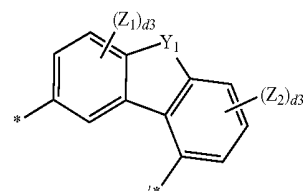
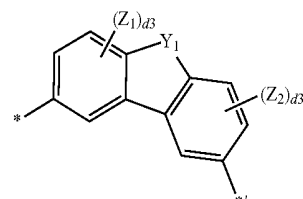
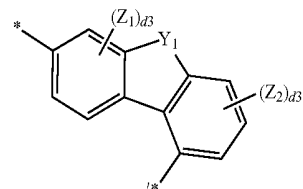
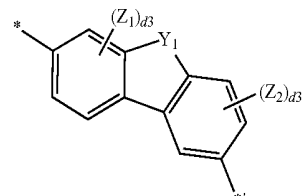
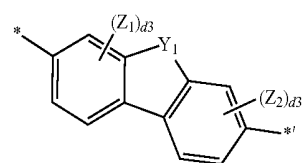
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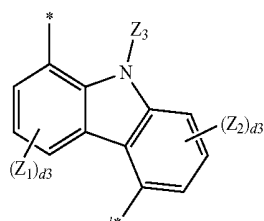
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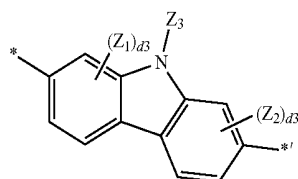
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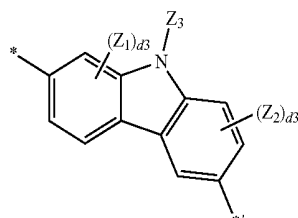
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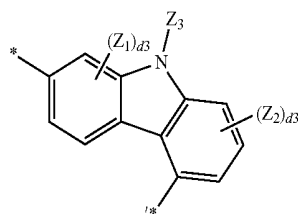
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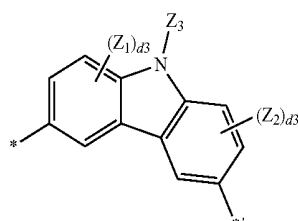
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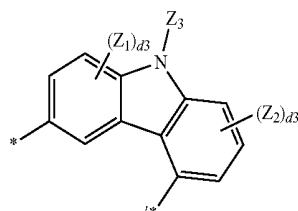
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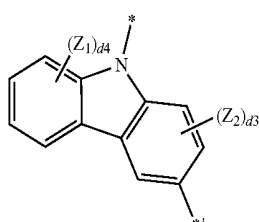
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3-55

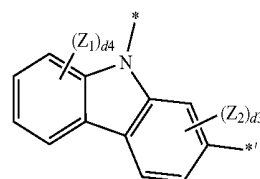


3-56



3-57

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3-58

[0039] Y_1 in Formulae 3-1 to 3-58 may be O, S, C(Z_3)(Z_4), N(Z_5), or Si(Z_6)(Z_7).

[0040] In Formulae 3-1 to 3-58, Z_1 to Z_7 may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, 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 pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a triazinyl group, a benzimidazolyl group, a phenanthrolinyl group, a biphenyl group, and a terphenyl group.

[0041] Z_3 and Z_4 may optionally be linked to form a Spiro structure,

[0042] Z_6 and Z_7 may optionally be linked to form a Spiro structure,

[0043] d_2 may be an integer from 0 to 2,

[0044] d_3 may be an integer from 0 to 3,

[0045] d_4 may be an integer from 0 to 4,

[0046] d_5 may be an integer from 0 to 5,

[0047] d_6 may be an integer from 0 to 6,

[0048] d_8 may be an integer from 0 to 8, and

[0049] * and *' each indicate a binding site to a neighboring atom.

[0050] R_1 and R_3 to R_{10} in Formula 1 may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, —Si(Q_{31})(Q_{32})(Q_{33}), P(=O)(Q_{31})(Q_{32}), 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 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, a biphenyl group, and a terphenyl group.

[0051] In one embodiment, R_1 and R_3 to R_{10} may each independently be selected from:

[0052] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, —Si(Q_{31})(Q_{32})(Q_{33}), a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl 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 naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-fluorene-benzofluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a biphenyl group, and a terphenyl group; and

[0053] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-fluorene-benzofluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, —Si(Q_{31})(Q_{32})(Q_{33}), a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-fluorene-benzofluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a biphenyl group, and a terphenyl group.

[0054] In one or more embodiments, R_1 may be selected from:

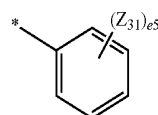
[0055] hydrogen, deuterium, a phenyl group, a naphthyl group, a fluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carba-

zoyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a biphenyl group, and a terphenyl group; and

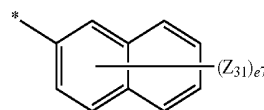
[0056] a phenyl group, a naphthyl group, a fluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, —Si(Q_{31})(Q_{32})(Q_{33}), a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a biphenyl group, and a terphenyl group, and

[0057] 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_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryl group substituted with a C_1 - C_{60} alkyl group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

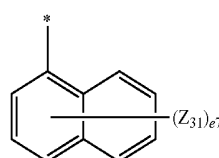
[0058] In one or more embodiments, R_1 may be selected from groups represented by Formulae A-1 to A-15:



A-1

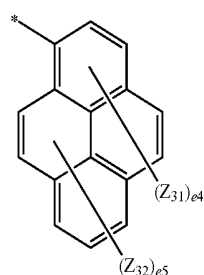
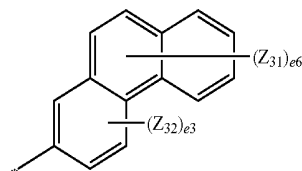
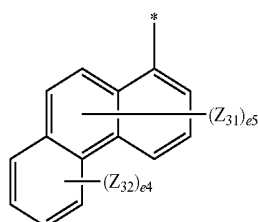
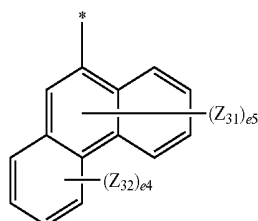
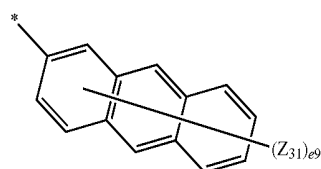
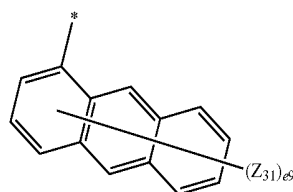
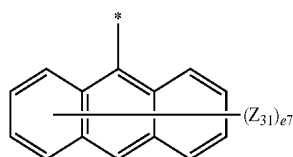


A-2



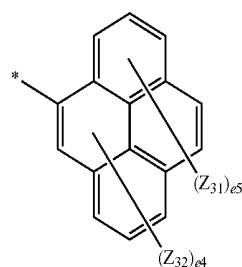
A-3

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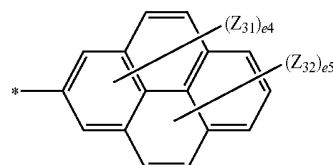


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A-4



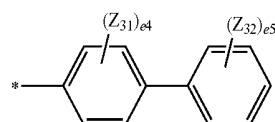
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A-11

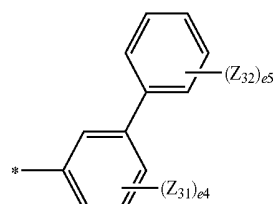
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A-6



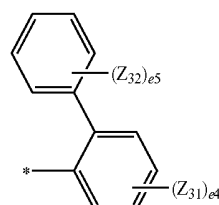
A-13

A-7



A-14

A-8



A-15

[0059] In Formulae A-1 to A-15,

[0060] Z_{31} and Z_{32} may each independently be selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkenyl group, a C_1 - C_{20} alkynyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, $-Si(Q_{31})(Q_{32})(Q_{33})$, $-N(Q_{31})(Q_{32})$, $-B(Q_{31})(Q_{32})$, $-C(=O)(Q_{31})$, $-S(=O)_2(Q_{31})$, and $-P(=O)(Q_{31})(Q_{32})$.

A-9

A-10

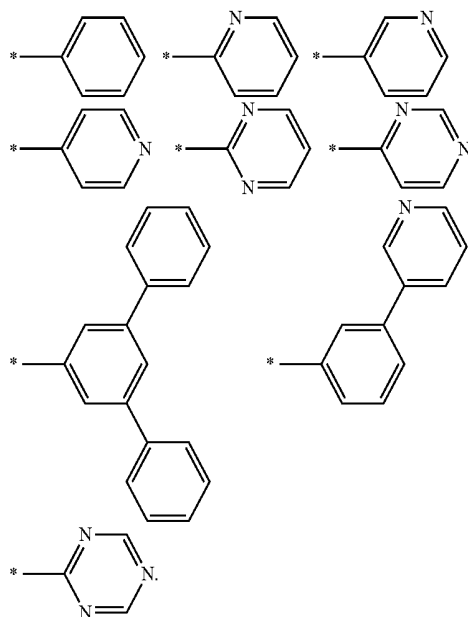
[0061] Q_{31} to Q_{33} are each independently selected from a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a phenyl group substituted with a C_1 - C_{10} alkyl group, a biphenyl group, a terphenyl group, a naphthyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothienophenyl group,

[0062] e_3 is an integer from 1 to 3,

[0063] e_4 is an integer from 1 to 4,

[0064] e_5 is an integer from 1 to 5,

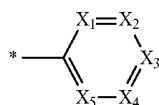
- [0065] e6 is an integer from 1 to 6,
 [0066] e7 is an integer from 1 to 7,
 [0067] e9 is an integer from 1 to 9, and
 [0068] * indicates a binding site to a neighboring atom.
 [0069] In one embodiment, Z_{31} and Z_{32} may each independently be hydrogen or a phenyl group.
 [0070] In one embodiment, R_1 may be selected from the following structures:



- [0071] In the above structures,
 [0072] * indicates a binding site to a neighboring atom.
 [0073] In one embodiment, R_2 may be (i) a C_6-C_{60} aryl group substituted with at least one electron withdrawing group or (ii) a substituted or unsubstituted π electron-depleted nitrogen-containing ring group.
 [0074] In one embodiment, the electron withdrawing group may be $-F$, $-Cl$, $-Br$, $-I$, a cyano group, or a C_1-C_{20} fluoroalkyl group, but embodiments of the present disclosure, are not limited thereto.
 [0075] In one or more embodiments, the electron withdrawing group may be $-F$, $-Cl$, a cyano group, $-CF_3$, or $-CF_2CF_3$, but embodiments of the present disclosure are not limited thereto.
 [0076] In one embodiment, the “ π electron-depleted nitrogen-containing ring” refers to a C_1-C_{60} heterocyclic group having at least one $*-N=*$ moiety as a ring-forming moiety.
 [0077] 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.
 [0078] Examples of the π electron-depleted nitrogen-containing ring include an imidazole, a pyrazole, a thiazole, an isothiazole, an oxazole, an isoxazole, a pyridine, a pyrazine,

a pyrimidine, a pyridazine, an indazole, a purine, a quinoline, an isoquinoline, a benzoquinoline, a phthalazine, a naphthyridine, a quinoxaline, a quinazoline, a cinnoline, a phenanthridine, an acridine, a phenanthroline, a phenazine, a benzimidazole, an isobenzothiazole, a benzoxazole, an isobenzoxazole, a triazole, a tetrazole, an oxadiazole, a triazine, a thiadiazole, an imidazopyridine, an imidazopyrimidine, and an azacarbazole, but embodiments of the present disclosure are not limited thereto.

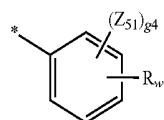
[0079] In one embodiment, R_2 may be represented by Formula 2.



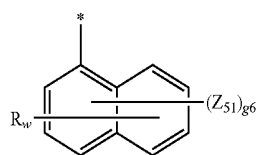
- [0080] In Formula 2, X_1 may be N or CAr_1 ,
 [0081] X_2 may be N or CAr_2 ,
 [0082] X_3 may be N or CAr_3 ,
 [0083] X_4 may be N or CAr_4 ,
 [0084] X_5 may be N or CAr_5 , and
 [0085] * indicates a binding site to a neighboring atom.
 [0086] In Formula 2, Ar_1 to Ar_5 may each independently be selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, $-Si(Q_{31})(Q_{32})(Q_{33})$, $P(=O)(Q_{31})(Q_{32})$, 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 monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, and Ar_1 to Ar_5 may optionally be linked to form a substituted or unsubstituted ring,
 [0087] provided that (i) at least one of X_1 to X_5 may be N, or (ii) at least one of Ar_1 to Ar_5 may be a substituted or unsubstituted π electron-depleted nitrogen-containing ring group or an electron withdrawing group, and
 [0088] 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_6-C_{60} aryl group substituted with a C_1-C_{60} alkyl group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.
 [0089] In one embodiment, Ar_1 to Ar_5 may each independently be selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group,

—Si(Q₃₁)(Q₃₂)(Q₃₃), a substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, and a substituted or unsubstituted C₁-C₆₀ heteroaryl group.

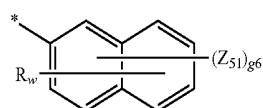
[0090] In one or more embodiments, R₂ may be selected from groups represented by Formulae W-1 to W-16 and N-1 to N-59:



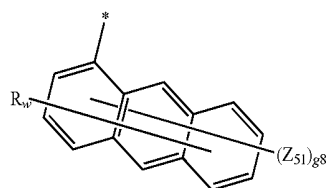
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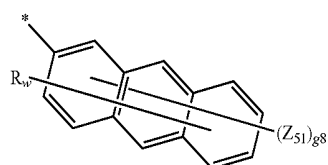
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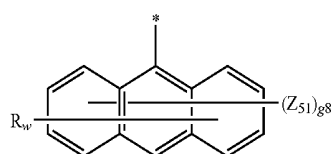
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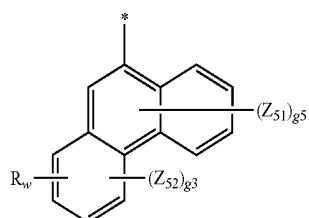
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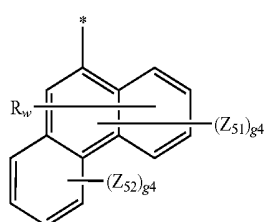
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W-6

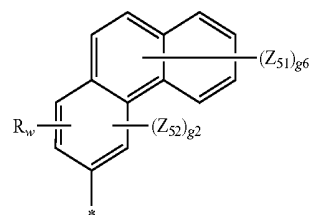


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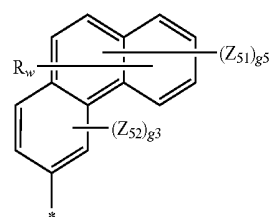


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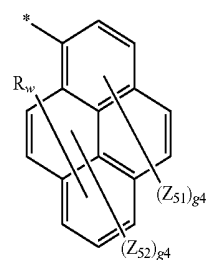
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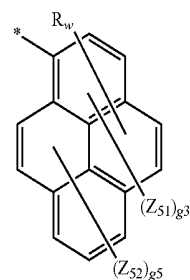
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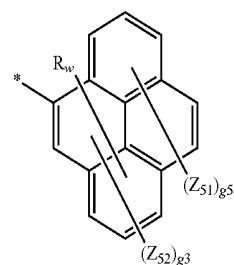
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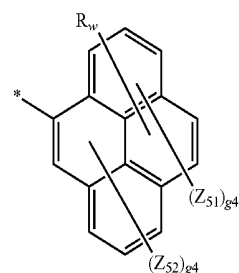
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W-12

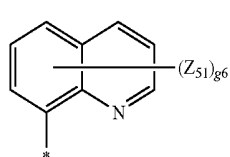
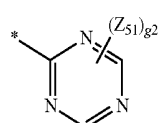
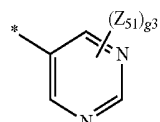
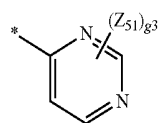
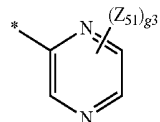
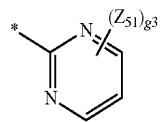
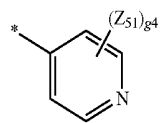
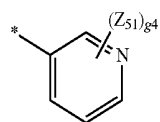
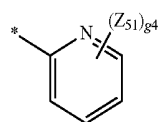
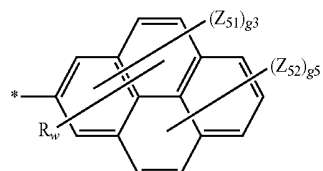
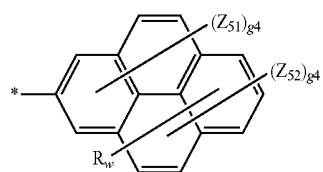


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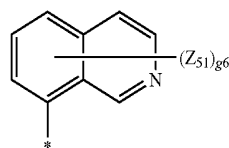
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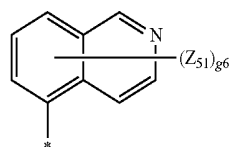
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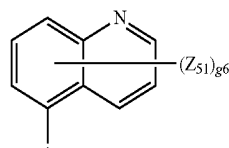
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W-16



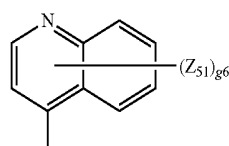
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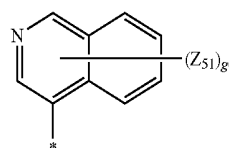
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N-2



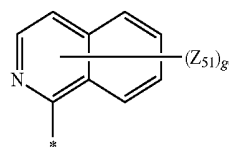
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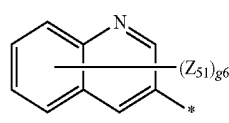
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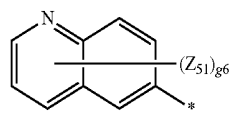
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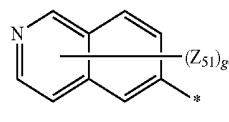
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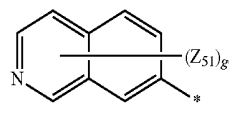
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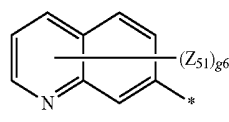
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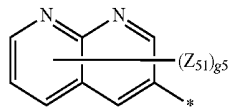
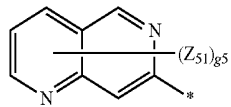
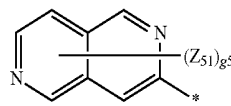
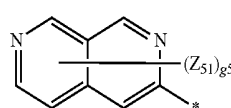
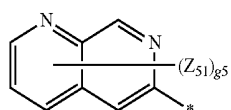
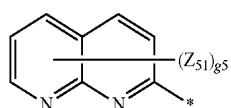
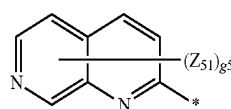
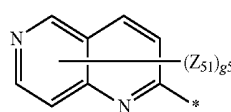
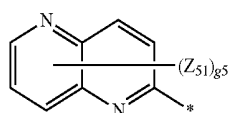
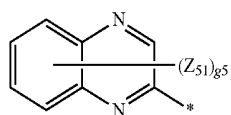
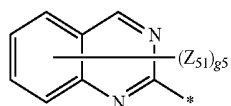
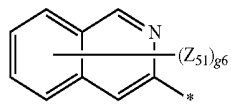
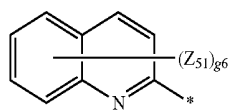
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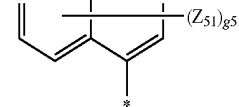
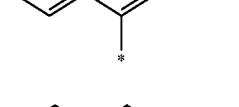
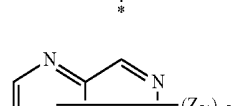
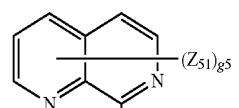
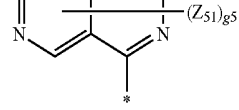
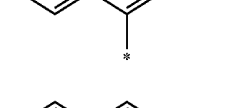
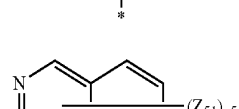
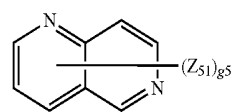
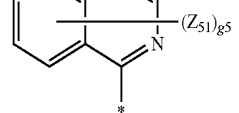
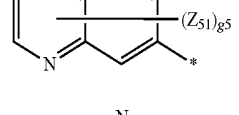
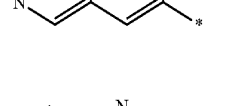
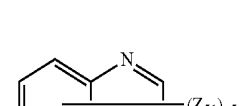
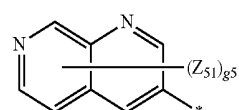


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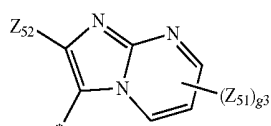
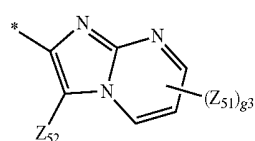
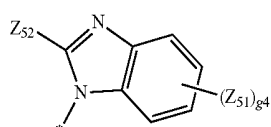
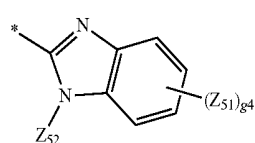
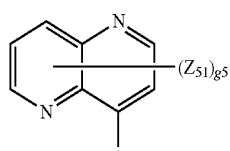
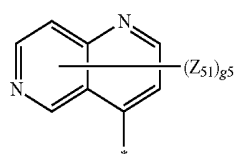
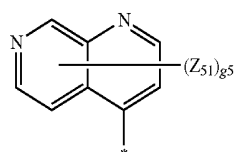
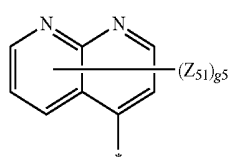
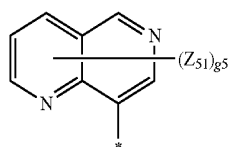
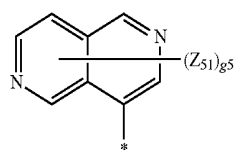
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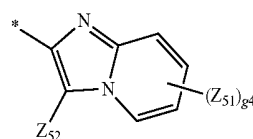


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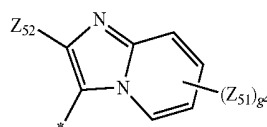
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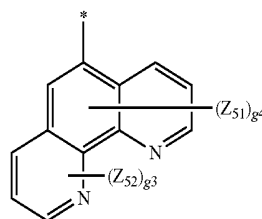
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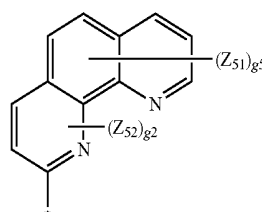
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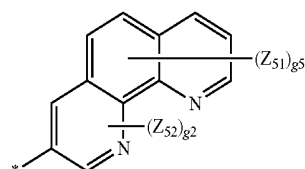
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N-47



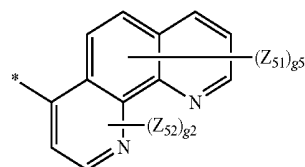
N-57

N-48



N-58

N-49



N-59

N-50

[0091] R_w in Formulae W-1 to W-16 may be selected from a cyano group, a C_1 - C_{20} fluoroalkyl group, and groups represented by Formulae N-1 to N-59.

N-51

[0092] In Formulae W-1 to W-16 and N-1 to N-59, Z_{51} and Z_{52} 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} fluoroalkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyrenyl group, an imidazolyl group, a pyrazole group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a triazinyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a

N-52

N-53

phthalazinyl group, a naphthyridinyl 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 oxadiazolyl group, a thiadiazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group,

[0093] g2 may be an integer from 0 to 2,

[0094] g3 may be an integer from 0 to 3,

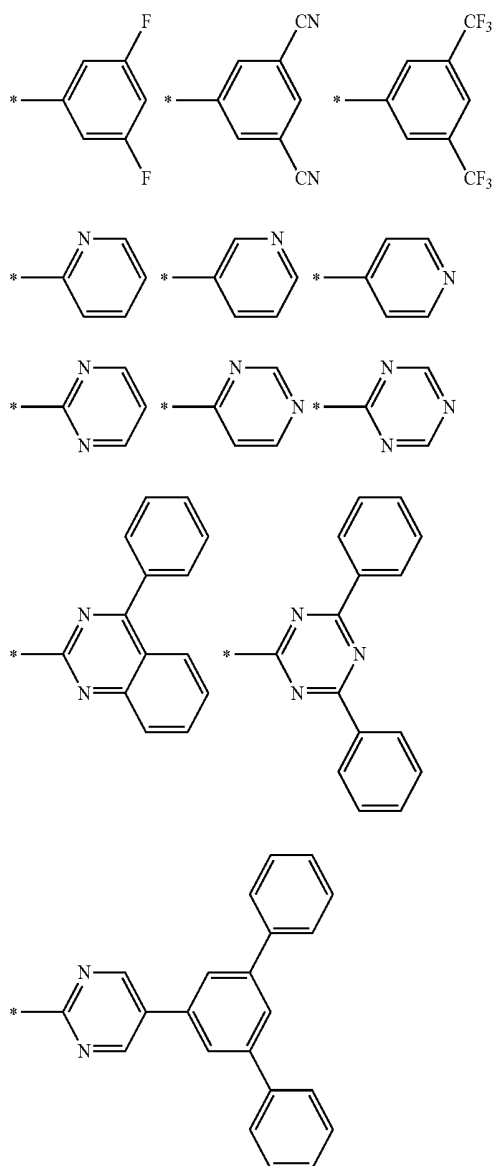
[0095] g4 may be an integer from 0 to 4,

[0096] g5 may be an integer from 0 to 5,

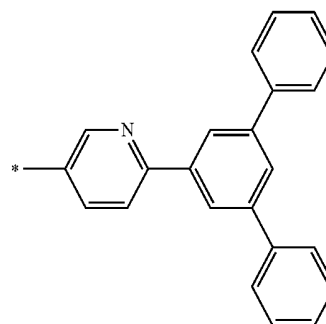
[0097] g6 may be an integer from 0 to 6, and

[0098] * indicates a binding site to a neighboring atom.

[0099] In one embodiment, R₂ may be selected from the following structures:



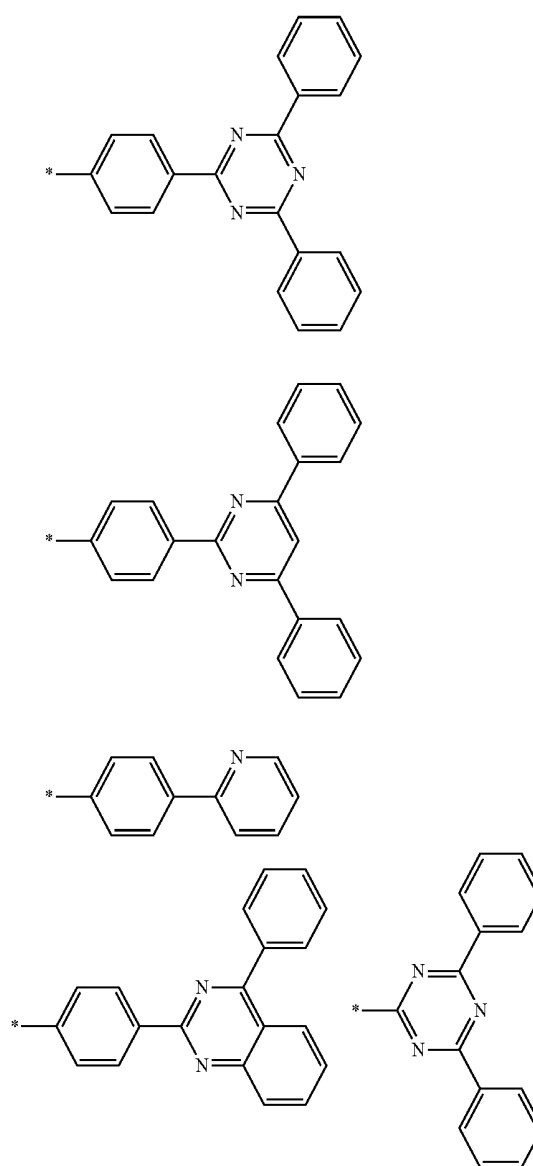
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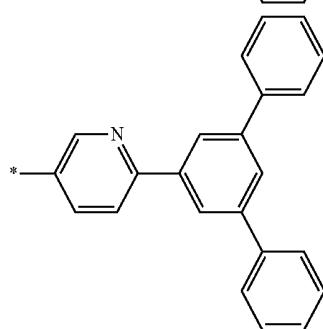
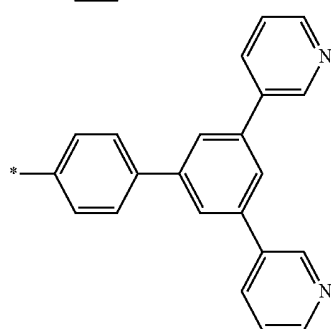
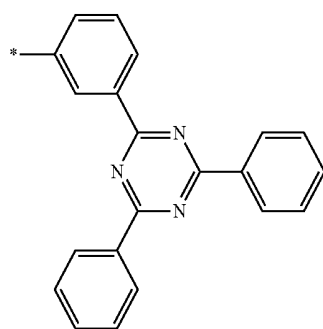
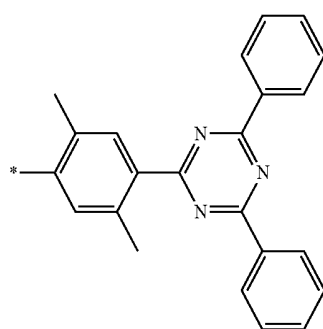
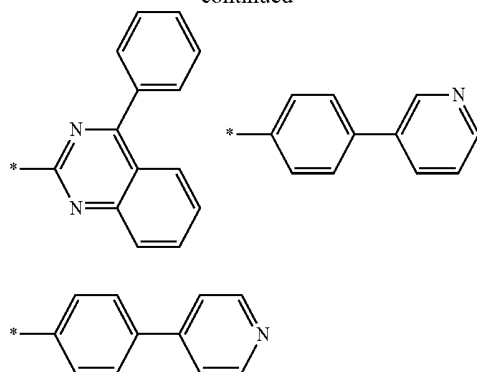
[0100] In the above structures,

[0101] * indicates a binding site to a neighboring atom.

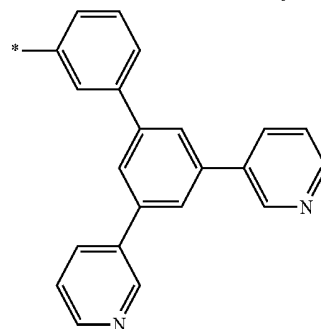
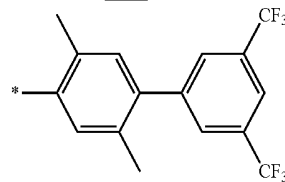
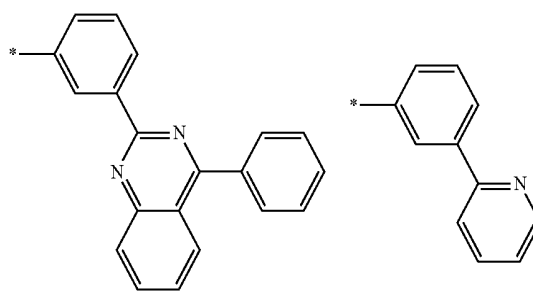
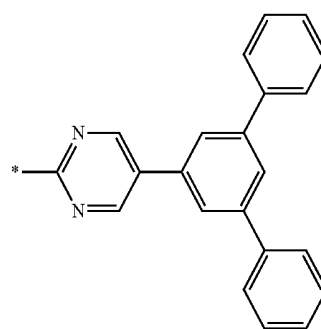
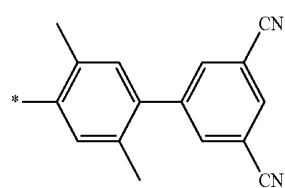
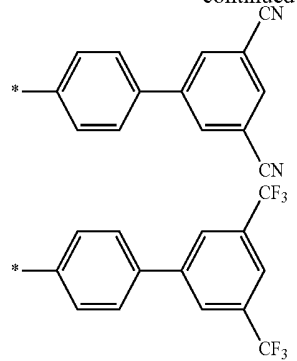
[0102] In one embodiment, -(L₂)_{a2}-(R₂)_{b2} may be selected from the following structures:

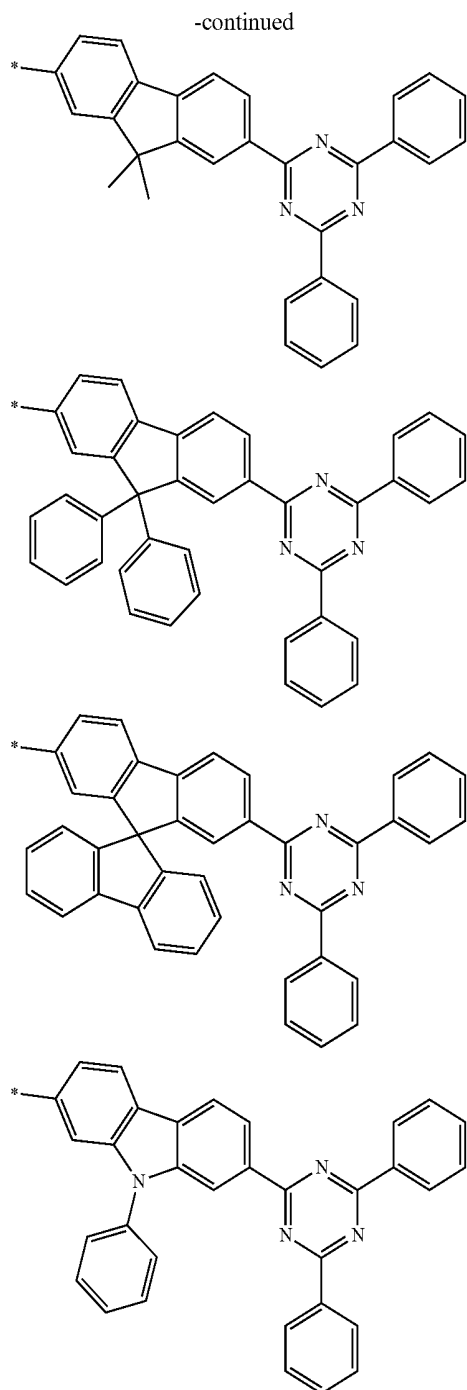


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[0103] In the above structures,

[0104] * indicates a binding site to a neighboring atom.

[0105] In one embodiment, R_3 to R_{10} may each independently be selected from:

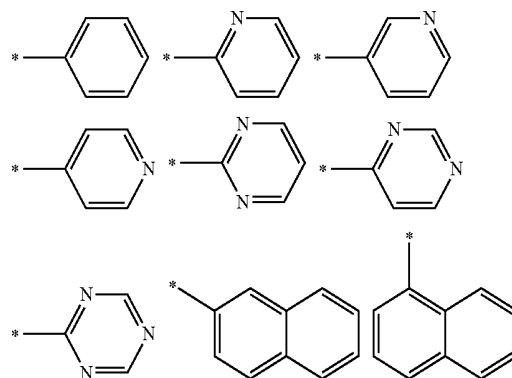
[0106] hydrogen, deuterium, a phenyl group, a naphthyl group, a fluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl

group, a dibenzofuranyl group, a dibenzothiophenyl group, a biphenyl group, and a terphenyl group; and

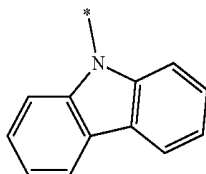
[0107] a phenyl group, a naphthyl group, a fluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, —Si(Q_{31})(Q_{32})(Q_{33}), a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a biphenyl group, and a terphenyl group, and

[0108] 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_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryl group substituted with a C_1 - C_{60} alkyl group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

[0109] In one or more embodiments, R_3 to R_{10} may each independently be selected from hydrogen or the following structures:



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[0110] In the above structures,

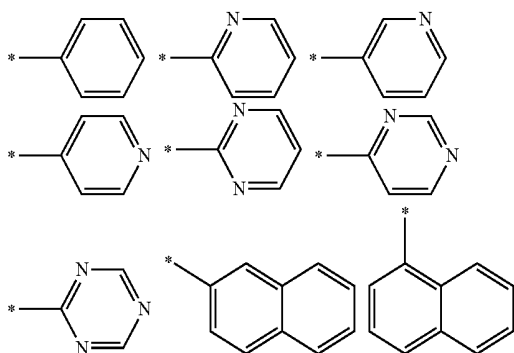
[0111] * indicates a binding site to a neighboring atom.

[0112] In one embodiment, at least one of R₄ and R₉ may be selected from:

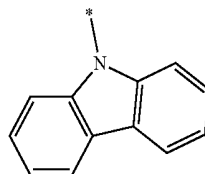
[0113] a phenyl group, a naphthyl group, a fluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a biphenyl group, and a terphenyl group; and

[0114] a phenyl group, a naphthyl group, a fluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a triazinyl group, a biphenyl group, and a terphenyl group.

[0115] In one or more embodiments, R₄ and R₉ may each independently be selected from the following structures:



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[0116] In the above structures,

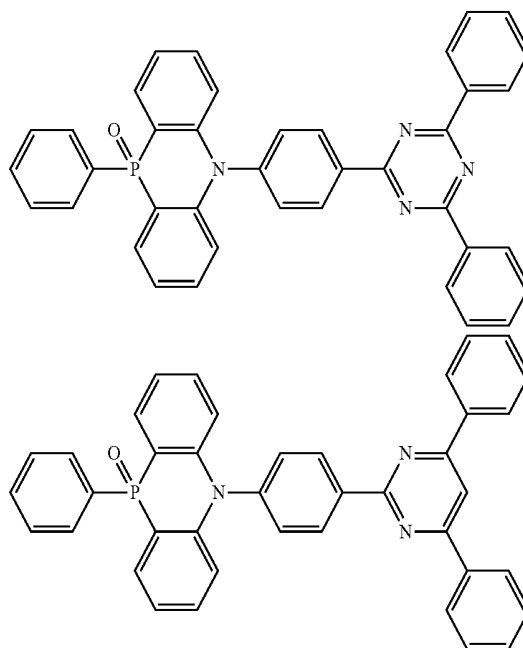
[0117] * indicates a binding site to a neighboring atom.

[0118] In one embodiment, R₃, R₅ to R₈, and R₁₀ 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, —Si(Q₃₁)(Q₃₂)(Q₃₃), a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, a pentyl group, an iso-amyl group, and a hexyl group, and

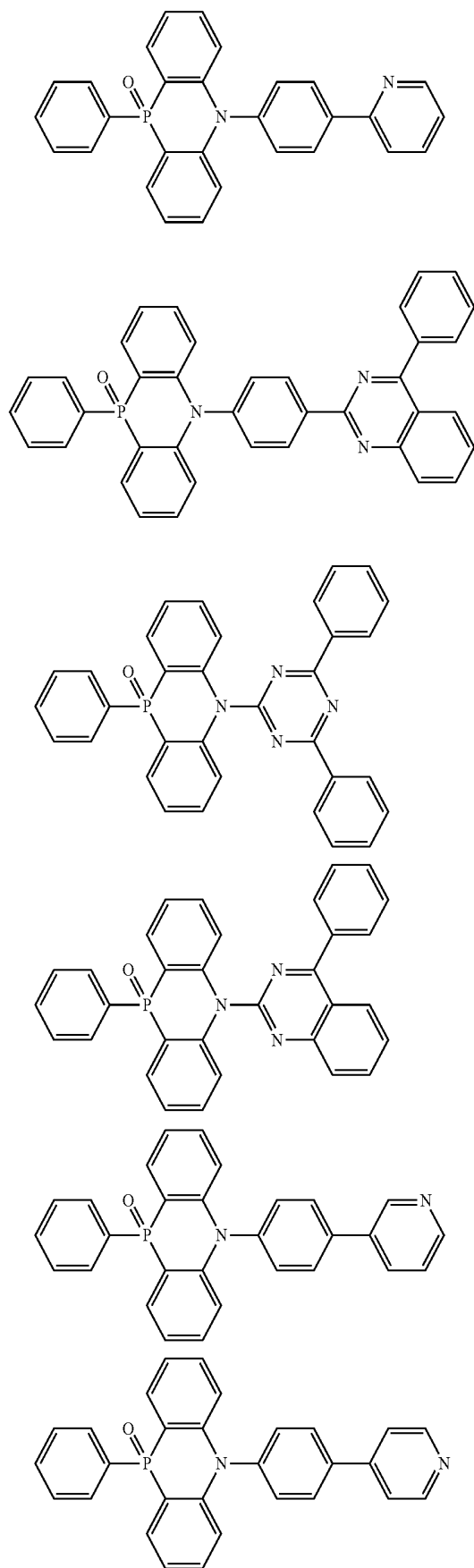
[0119] Q₃₁ to Q₃₃ may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryl group substituted with a C₁-C₆₀ alkyl group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

[0120] In one embodiment, R₃, R₅ to R₈, and R₁₀ may each be hydrogen (e.g., R₃, R₅ to R₈, and R₁₀ may all be hydrogen).

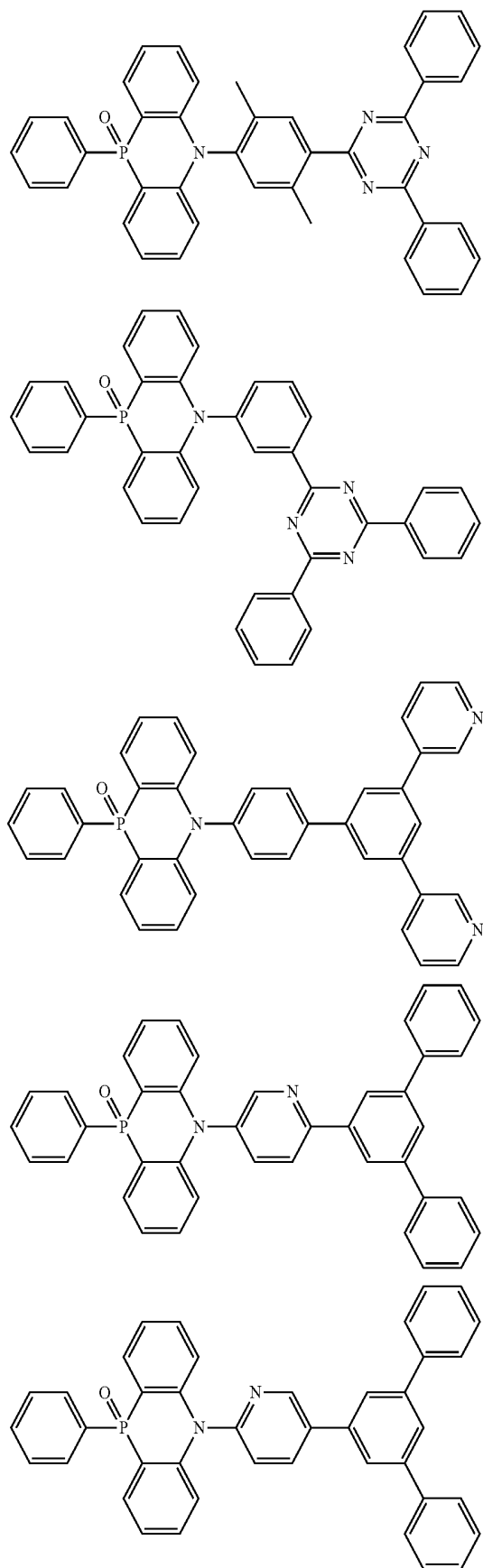
[0121] In one embodiment, the heterocyclic compound may be one of the following compounds, but embodiments of the present disclosure are not limited thereto:



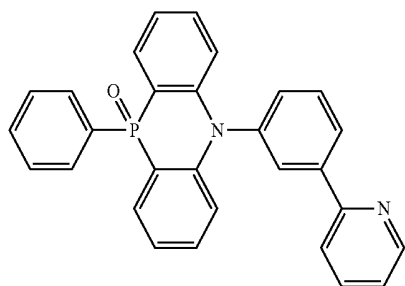
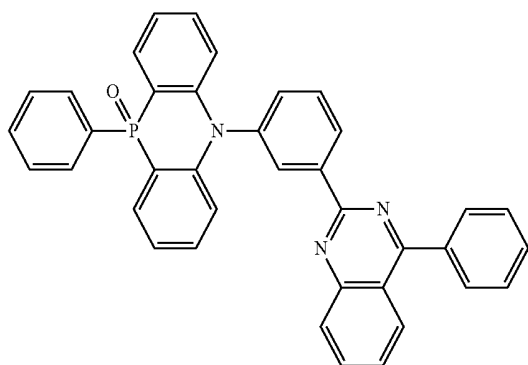
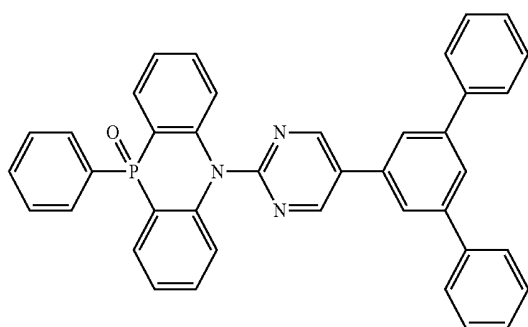
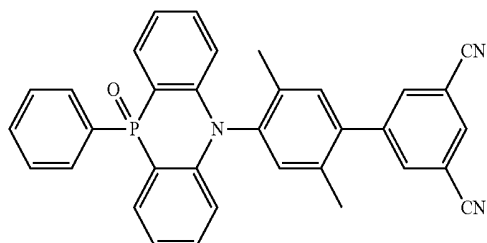
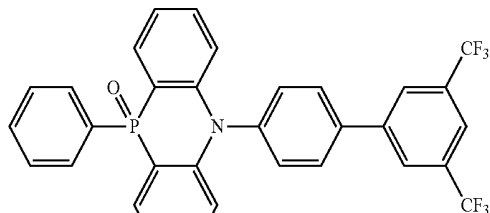
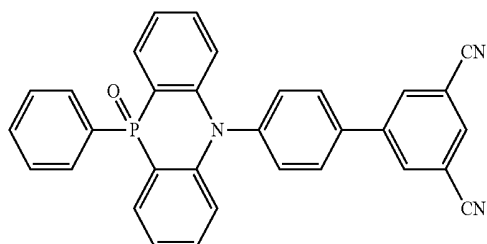
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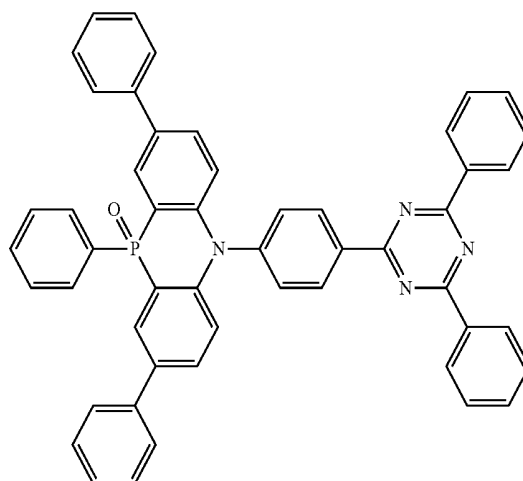
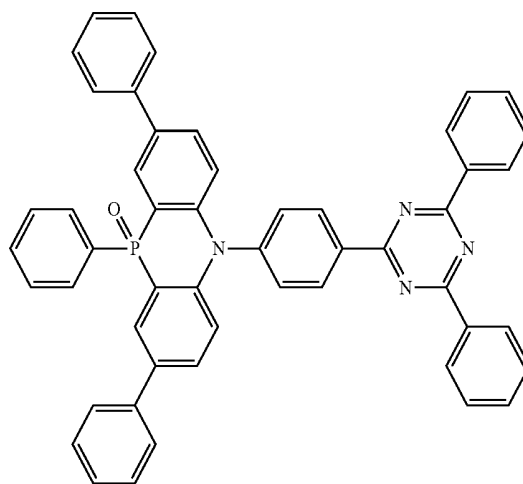
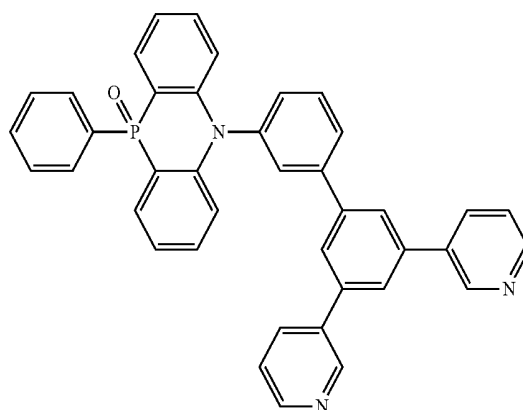
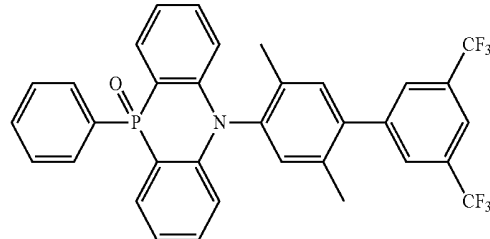
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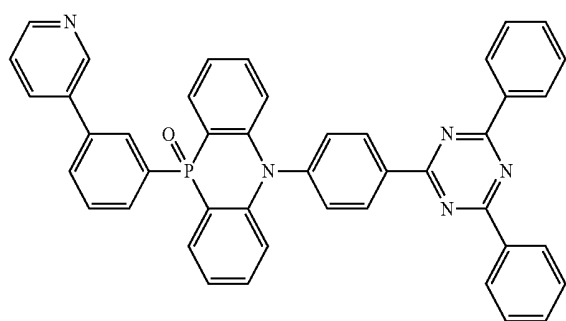
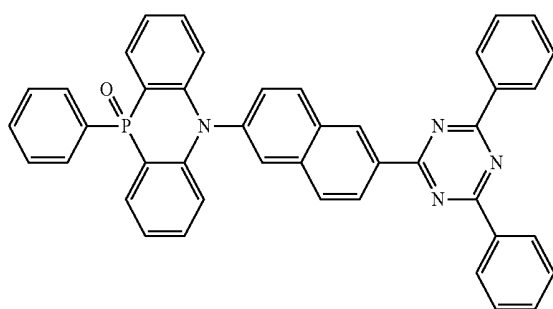
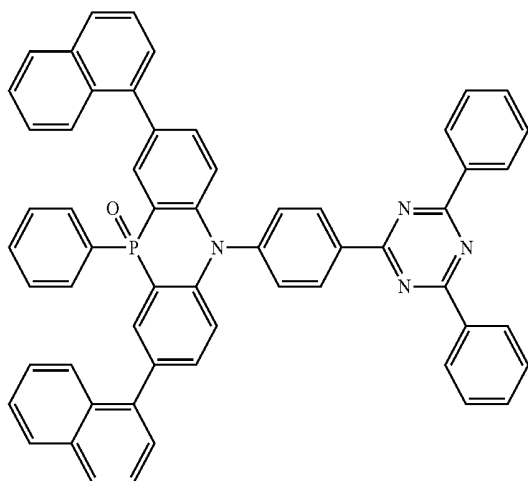
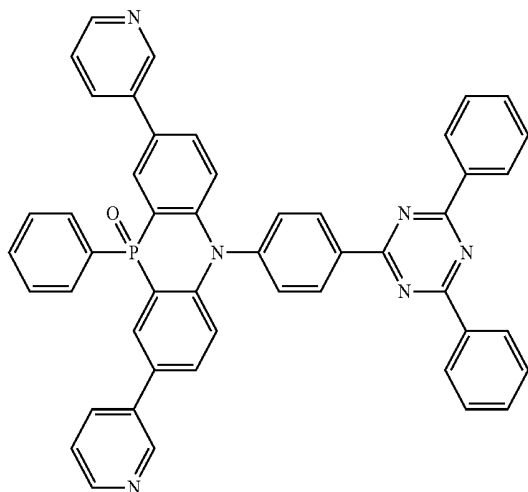
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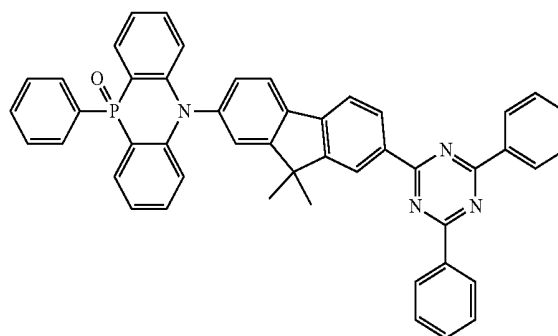
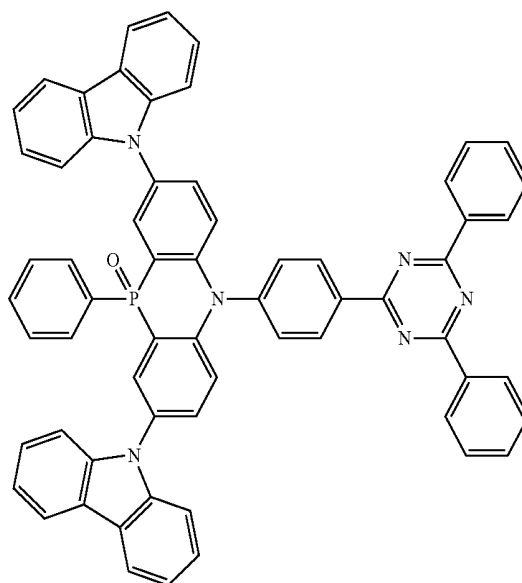
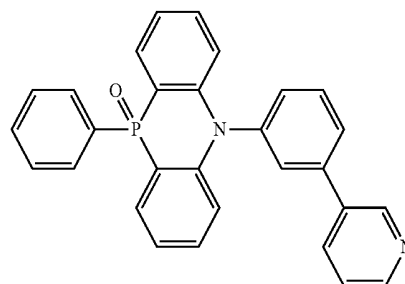
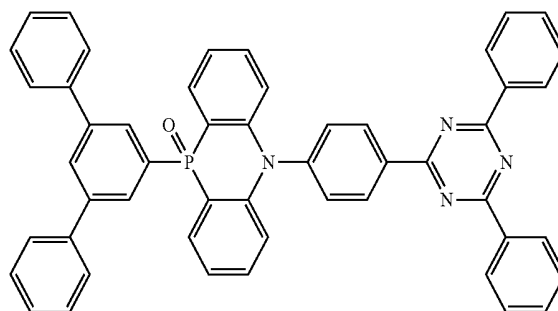
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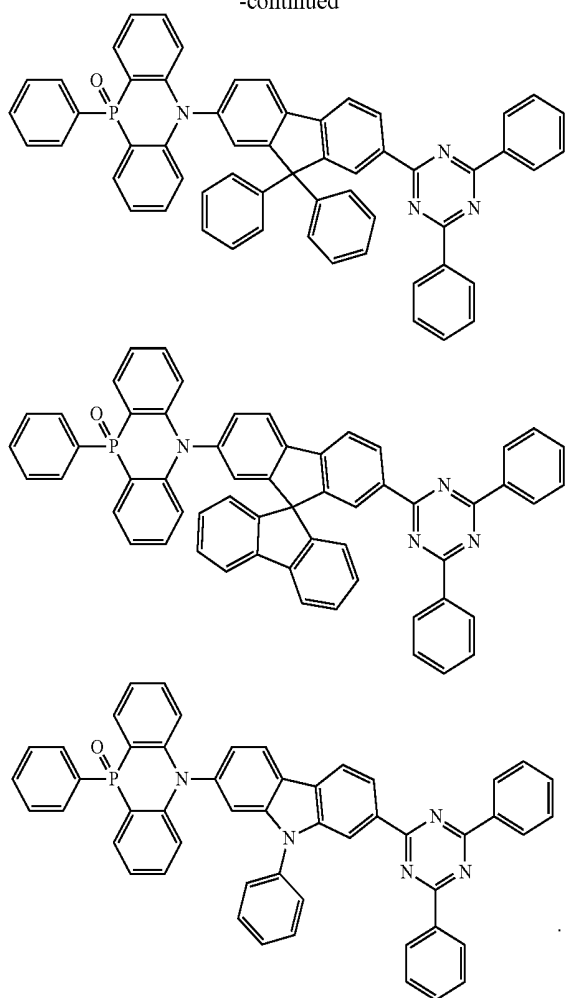
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[0122] The heterocyclic compound represented by Formula 1 is a compound having a structure in which a substituent having an electron withdrawing property is N-substituted in a phenophosphazine core. Since the heterocyclic compound has a phosphine oxide (P=O) structure, triplet energy thereof is high. Thus, the heterocyclic compound may be variously applied as a phosphorescent material (e.g., the heterocyclic compound may be used as a phosphorescent material in various suitable applications). While a compound that is similar to the heterocyclic compound but has no phosphine oxide structure emits green light, the heterocyclic compound according to embodiments of the present disclosure emits blue light.

[0123] Since the phosphine oxide core itself has high triplet energy, the heterocyclic compound may be variously applied as a phosphorescent material (e.g., the heterocyclic compound may be used as a phosphorescent material in various suitable applications). However, when the heterocyclic compound is applied to a device as a host, electron characteristics are low, and thus a driving voltage greatly increases. Therefore, in order to prevent such a phenomenon (or to reduce a likelihood or degree of such a phenomenon), the heterocyclic compound is imparted with bipolar characteristics. To this end, electron characteristics may be supplemented by using a structure in which a substituent having an electron withdrawing property is N-substituted, like the

heterocyclic compound. As a result, when the heterocyclic compound is applied to a device, a driving voltage, efficiency, and lifespan of the device may be improved.

[0124] Therefore, an electronic device, for example, an organic light-emitting device, which includes the heterocyclic compound represented by Formula 1, may have a low driving voltage, high current density, and high efficiency.

[0125] A synthesis method for the heterocyclic compound represented by Formula 1 would be apparent to those of ordinary skill in the art by referring to the following examples.

[0126] At least one of the heterocyclic compound of Formula 1 may be used between a pair of electrodes of an organic light-emitting device. For example, the heterocyclic compound may be included in at least one layer selected from a hole transport region and an emission layer. In one or more embodiments, the heterocyclic compound of Formula 1 may be used as a material for a capping layer located outside of a pair of electrodes of an organic light-emitting device.

[0127] According to another aspect of embodiments, an organic light-emitting device includes: a first electrode, a second electrode, and an organic layer between the first electrode and the second electrode, the organic layer including an emission layer and at least one heterocyclic compound represented by Formula 1 described above.

[0128] The expression “(an organic layer) includes at least one of the heterocyclic compounds,” as used herein, may include a case in which “(an organic layer) includes identical heterocyclic compounds represented by Formula 1” and a case in which “(an organic layer) includes two or more different heterocyclic compounds represented by Formula 1.”

[0129] For example, the organic layer may include, as the heterocyclic compound, Compound 1 alone. 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 heterocyclic compound, Compound 1 and Compound 2. In this regard, Compound 1 and Compound 2 may exist in an identical layer (for example, Compound 1 and Compound 2 may all exist in an emission layer), or different layers (for example, Compound 1 may exist in an emission layer and Compound 2 may exist in an electron transport layer).

[0130] According to one embodiment,

[0131] the first electrode of the organic light-emitting device may be an anode,

[0132] the second electrode of the organic light-emitting device may be a cathode,

[0133] the organic layer of the organic light-emitting device 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,

[0134] the hole transport region may include at least one layer selected from a hole injection layer, a hole transport layer, a buffer layer, an emission auxiliary layer, and an electron blocking layer, and

[0135] the electron transport region may include an electron transport region including at least one selected from a hole blocking layer, an electron transport layer, and an electron injection layer. Herein, the heterocyclic compound represented by Formula 1 may be included in the electron transport region.

[0136] In one embodiment, the electron transport region of the organic light-emitting device may include an electron transport layer and an electron injection layer, and at least one of the electron transport layer and the electron injection layer may include the heterocyclic compound represented by Formula 1. However, embodiments of the present disclosure are not limited thereto.

[0137] At least one layer selected from the electron transport layer and the electron injection layer may include an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare earth metal complex, or any combinations thereof. As used herein, the terms “combination thereof” and “combinations thereof” may refer to a chemical combination (e.g., an alloy or chemical compound), a mixture, or a laminated structure of components.

[0138] The emission layer in the organic light emitting device may include a dopant and a host, and the host may include at least one selected from an anthracene-based compound, a pyrene-based compound, and a spiro-bifluorene-based compound.

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

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

[0141] Hereinafter, the structure of the organic light-emitting device 10 according to an embodiment and a method of manufacturing the organic light-emitting device 10 will be described in connection with the accompanying drawing.

[0142] In the accompanying drawing, a substrate may be additionally disposed under the first electrode 110 or above the second electrode 190. The substrate may be a glass substrate or a plastic substrate, each having excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and water resistance.

[0143] The first electrode 110 may be formed by depositing or sputtering a material for forming the first electrode 110 on the substrate. When the first electrode 110 is an anode, the material for a first electrode may be selected from materials with a high work function to facilitate hole injection.

[0144] The first electrode 110 may be a reflective electrode, a semi-transmissive electrode, or a transmissive electrode. When the first electrode 110 is a transmissive electrode, a material for forming a first electrode may be selected from indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO₂), zinc oxide (ZnO), and any combinations 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, as a material for forming the first electrode 110, magnesium (Mg), silver (Ag), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), magnesium-silver (Mg—Ag), or any combination thereof may be used. However, the material for forming the first electrode 110 is not limited thereto.

[0145] The first electrode 110 may have a single-layered structure, or a multi-layered structure including two or more layers. For example, the first electrode 110 may have a three-layered structure of ITO/Ag/ITO, but the structure of the first electrode 110 is not limited thereto.

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

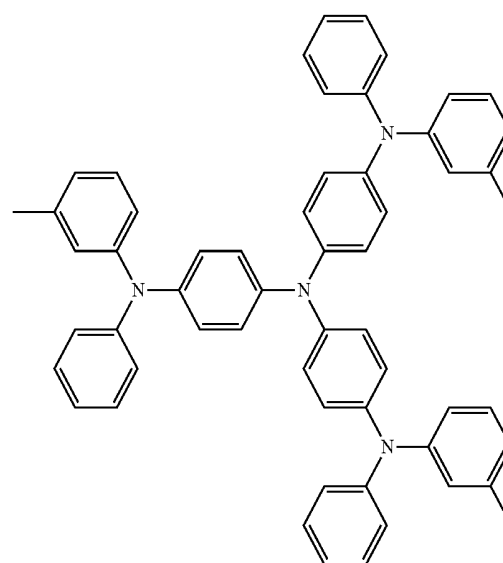
[0147] The organic layer 150 may further include a hole transport region between the first electrode 110 and the emission layer, and an electron transport region between the emission layer and the second electrode 190.

[0148] 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.

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

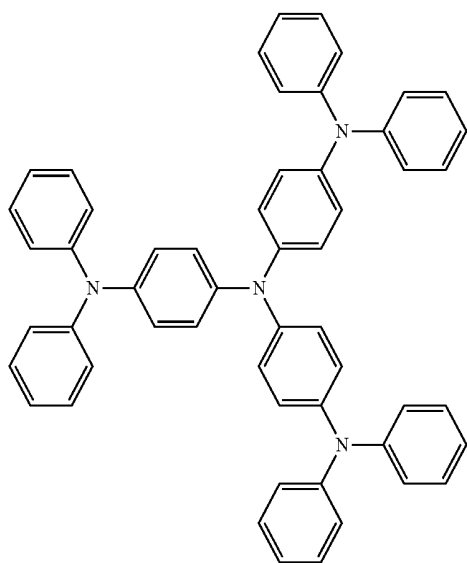
[0150] For example, the hole transport region may have a single-layered structure including a single layer including a plurality of different materials, or a multi-layered structure having a hole injection layer/hole transport layer structure, a hole injection layer/hole transport layer/emission auxiliary layer structure, a hole injection layer/emission auxiliary layer structure, a hole transport layer/emission auxiliary layer structure, or a hole injection layer/hole transport layer/electron blocking layer structure, wherein for each structure, constituting layers are sequentially stacked from the first electrode 110 in this stated order, but the structure of the hole transport region is not limited thereto.

[0151] The hole transport region may include at least one selected from m-MTDATA, TDATA, 2-TNATA, NPB (NPD), 13-NPB, TPD, Spiro-TPD, Spiro-NPB, methylated-NPB, TAPC, HMTPD, 4,4',4"-tris(N-carbazolyl)triphenylamine (TCTA), polyaniline/dodecylbenzenesulfonic acid (PANI/DBSA), poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate) (PEDOT/PSS), polyaniline/camphor sulfonic acid (PANI/CSA), polyaniline/poly(4-styrenesulfonate) (PANT/PSS), a compound represented by Formula 201, and a compound represented by Formula 202:

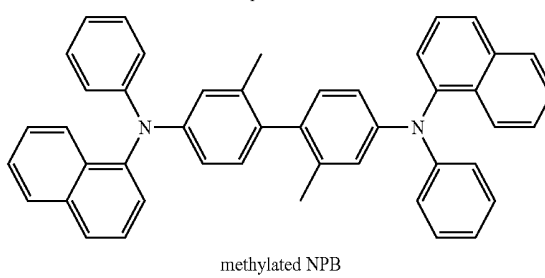
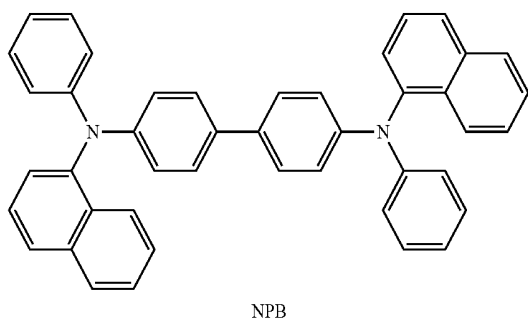
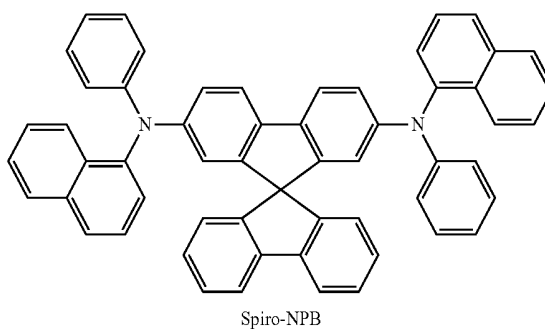
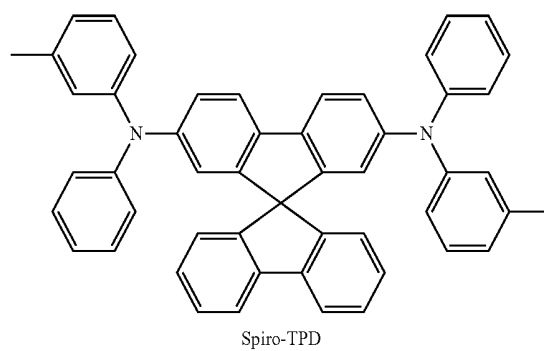
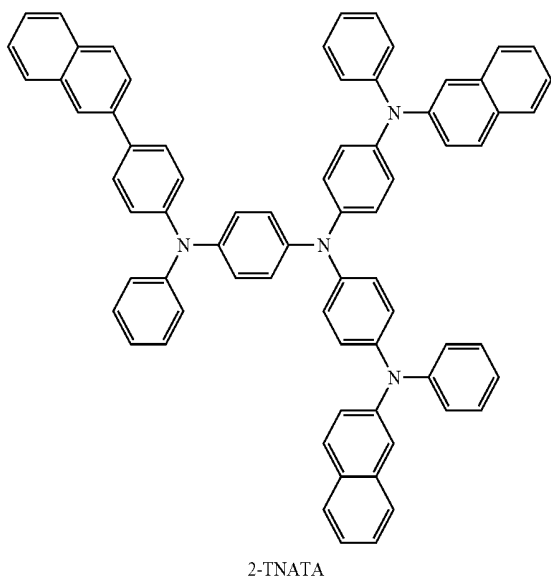
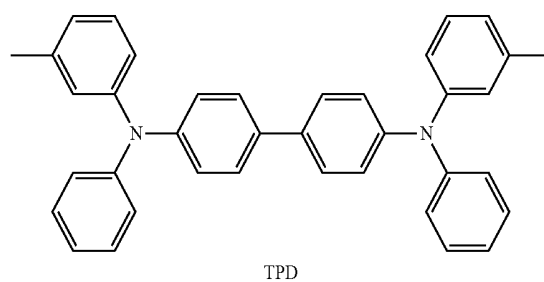
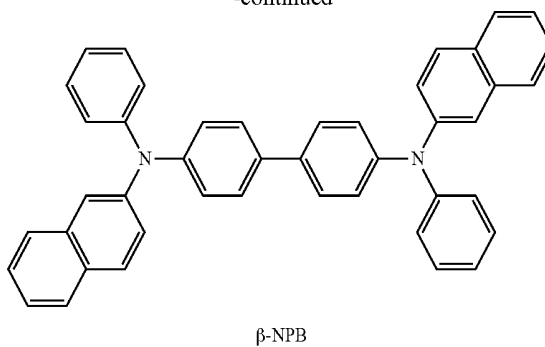


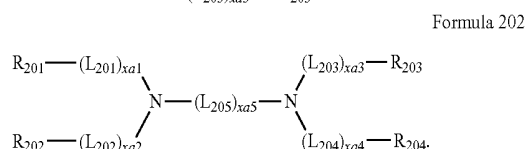
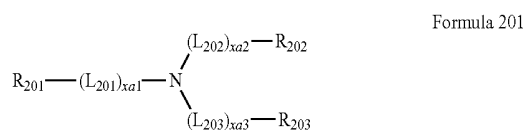
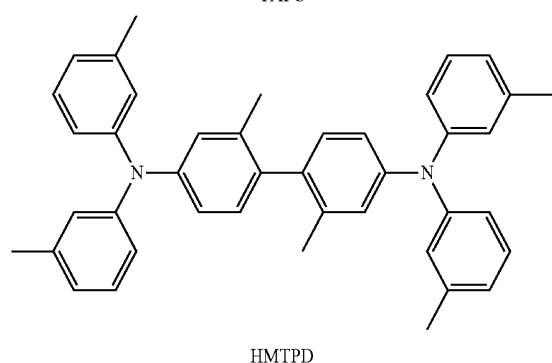
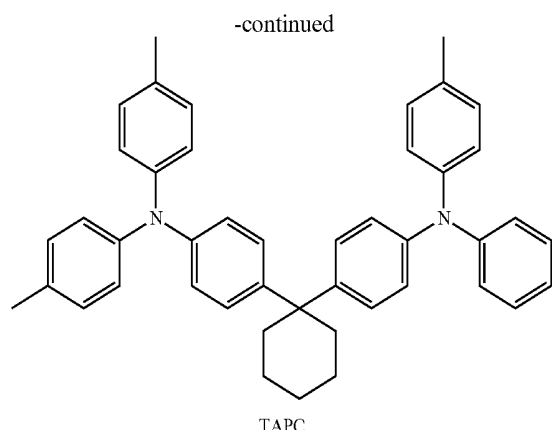
m-MTDATA

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[0152] In Formulae 201 and 202,

[0153] 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 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,

[0154] L_{205} may be selected from $^*\text{—O—}^*$, $^*\text{—S—}^*$, $^*\text{—N}(\text{Q}_{201})\text{—}^*$, 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,

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

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

[0157] 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.

[0158] In one embodiment, 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.

[0159] In one embodiment, in Formulae 201 and 202,

[0160] L_{201} to L_{205} may each independently be selected from:

[0161] a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylenylene group, a heptalenylene group, an indacenylene group, an acenaphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthrenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a rubicenylene group, a coronenylene group, an ovalenylene group, a thiophenylene group, a furanylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, and a pyridinylenylene group; and

[0162] a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylenylene group, a heptalenylene group, an indacenylene group, an acenaphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthrenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a rubicenylene group, a coronenylene group, an ovalenylene group, a thiophenylene group, a furanylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, and a pyridinylenylene group, each substituted with at least one selected from deuterium, —F , —Cl , —Br , —I , a hydroxyl group, a cyano group, a nitro

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

[0163] 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.

[0164] In one or more embodiments, xa1 to xa4 may each independently be 0, 1 or 2.

[0165] In one or more embodiments, xa5 may be 1, 2, 3, or 4.

[0166] 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;

[0167] a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a 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 substi-

tuted 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

[0168] Q_{31} to Q_{33} are the same as described above.

[0169] In one or more embodiments, at least one selected from R_{201} to R_{203} in Formula 201 may each independently be selected from:

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

[0171] a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, —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;

[0172] but embodiments of the present disclosure are not limited thereto.

[0173] 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.

[0174] In one or more embodiments, at least one selected from R_{201} to R_{204} in Formula 202 may be selected from:

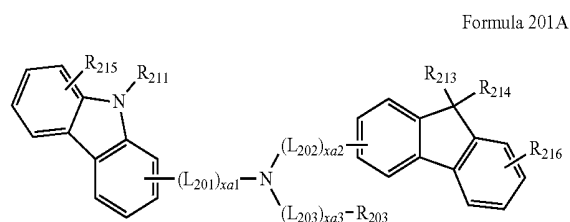
[0175] a carbazolyl group; and

[0176] 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

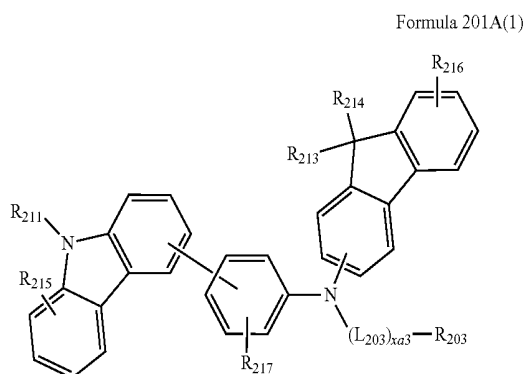
group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothio-phenyl group;

[0177] but embodiments of the present disclosure are not limited thereto.

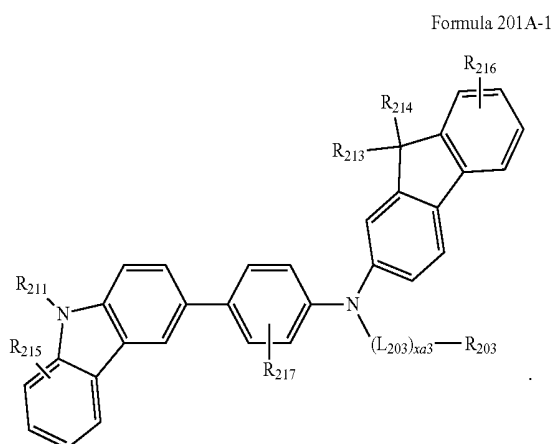
[0178] The compound represented by Formula 201 may be represented by Formula 201A:



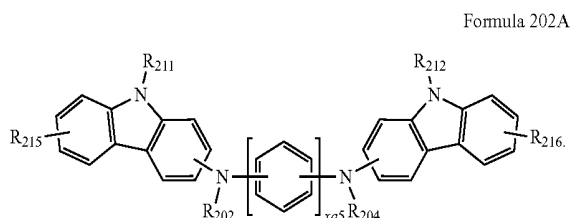
[0179] In one embodiment, the compound represented by Formula 201 may be represented by Formula 201A(1) below, but embodiments of the present disclosure are not limited thereto:



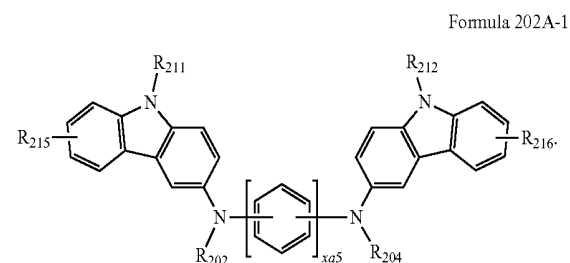
[0180] In one embodiment, the compound represented by Formula 201 may be represented by Formula 201A-1 below, but embodiments of the present disclosure are not limited thereto:



[0181] In one embodiment, the compound represented by Formula 202 may be represented by Formula 202A:



[0182] In one embodiment, the compound represented by Formula 202 may be represented by Formula 202A-1:



[0183] In Formulae 201A, 201A(1), 201A-1, 202A, and 202A-1,

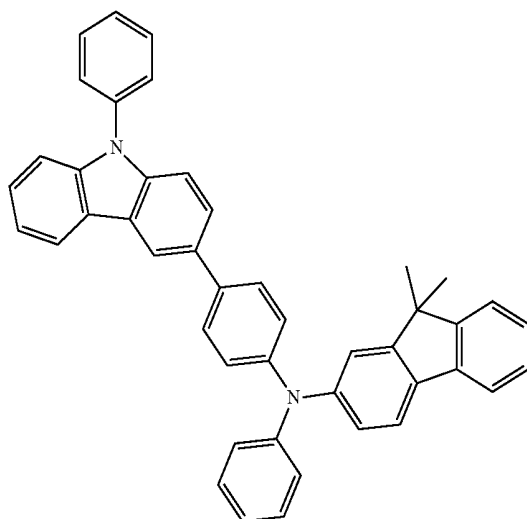
[0184] L_{201} to L_{203} , $xa1$ to $xa3$, $xa5$ and R_{202} to R_{204} are the same as described above,

[0185] R_{211} and R_{212} are the same as described in connection with R_{203} ,

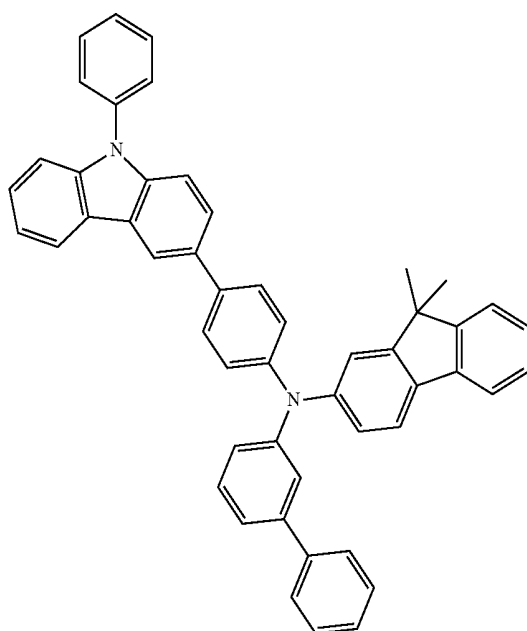
[0186] R_{213} to R_{217} may each independently be selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1 - C_{10} alkyl group, a phenyl group substituted with $-F$, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group.

[0187] 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

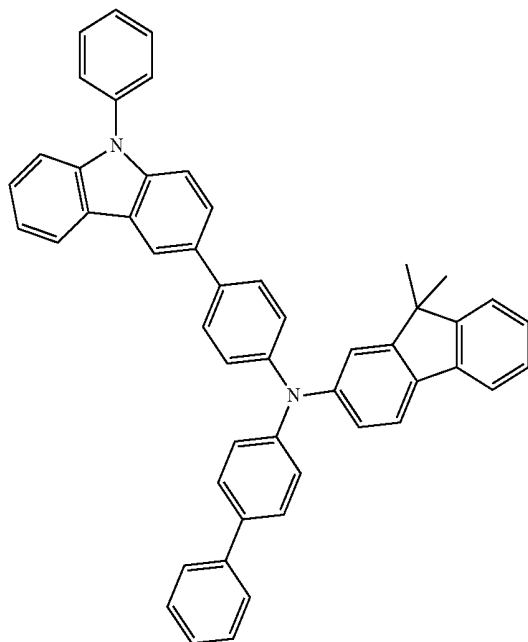


HT2

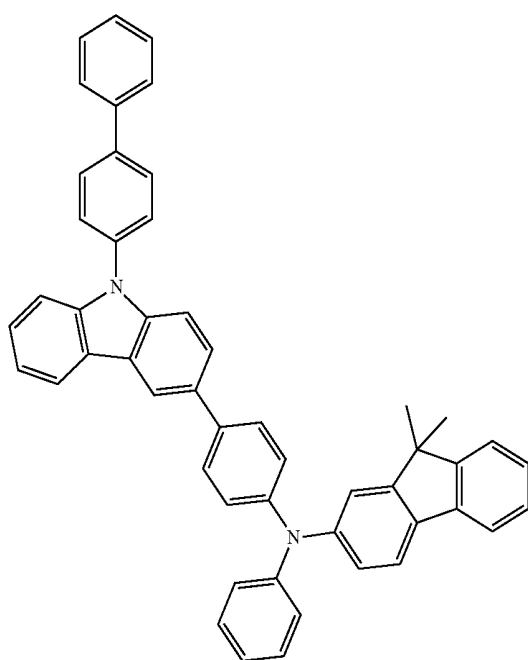


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HT3

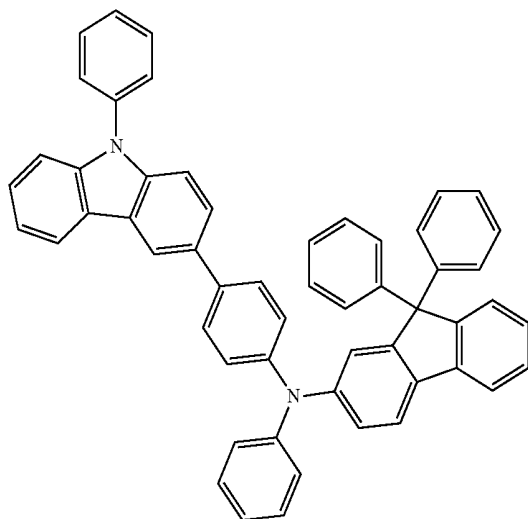


HT4

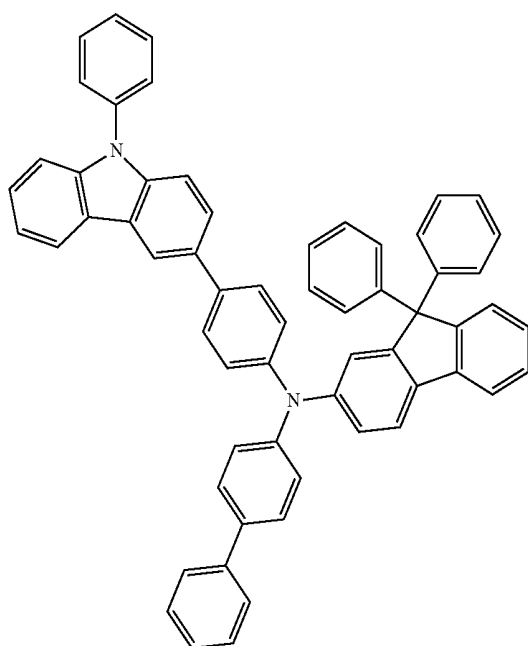


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HT5

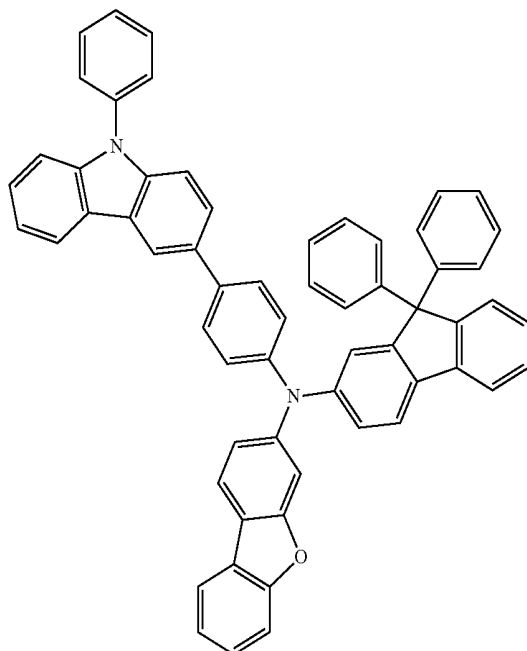


HT6

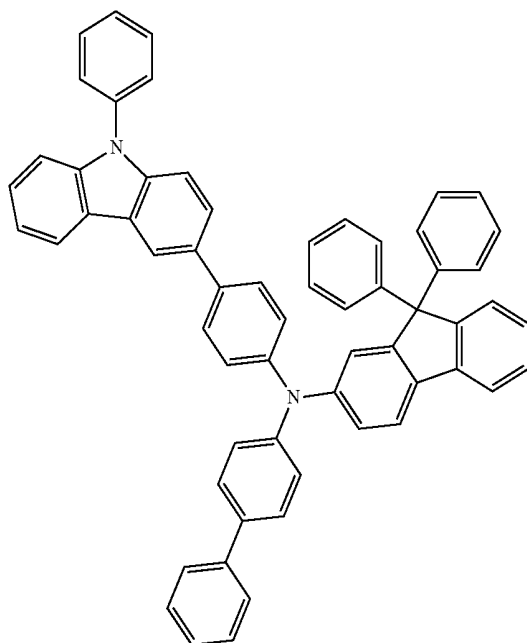


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HT7

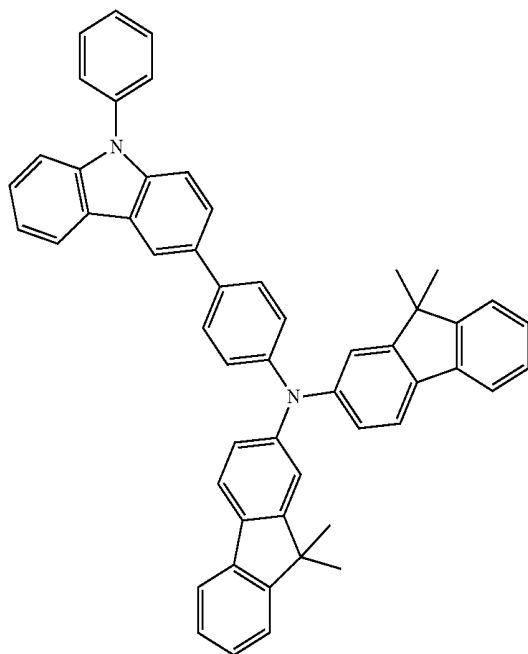


HT8

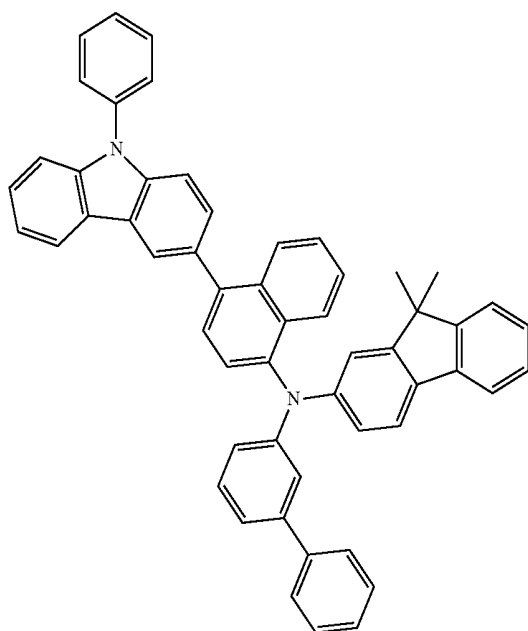


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HT9

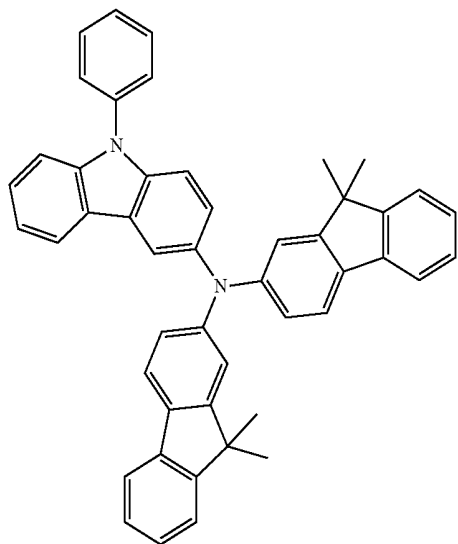


HT10

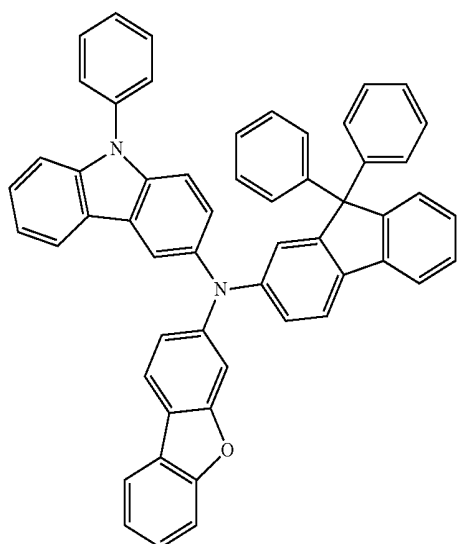


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HT11

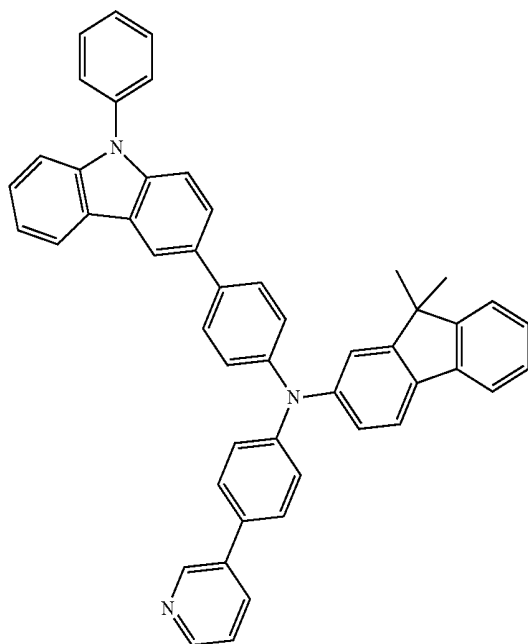


HT12

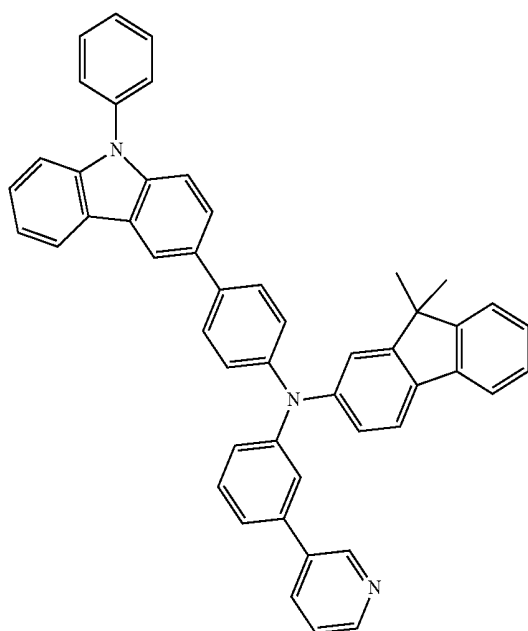


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HT13

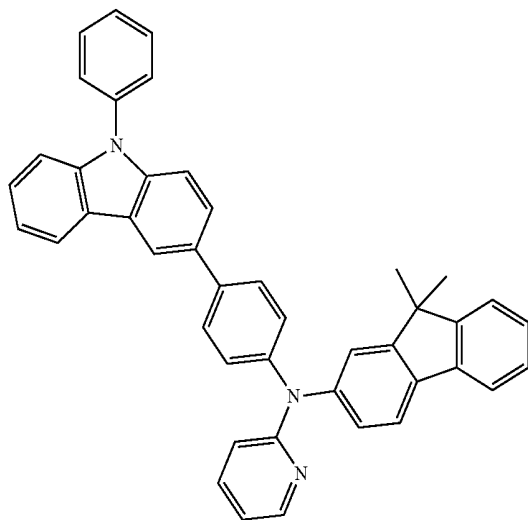


HT14

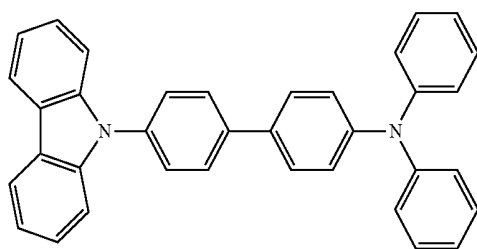


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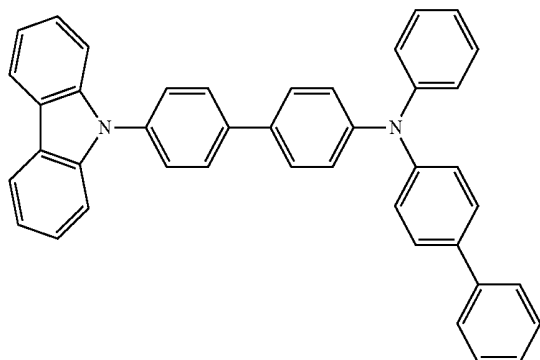
HT15



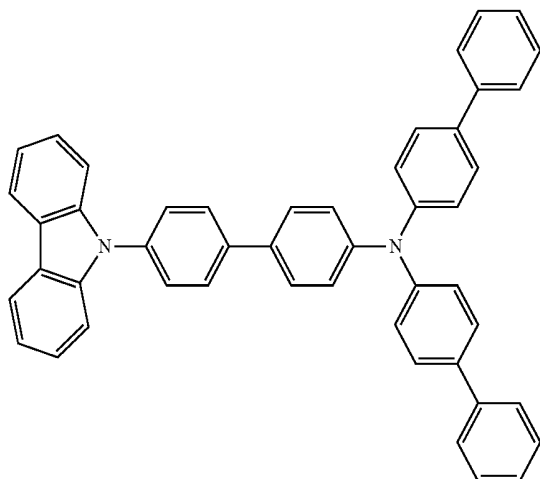
HT16



HT17

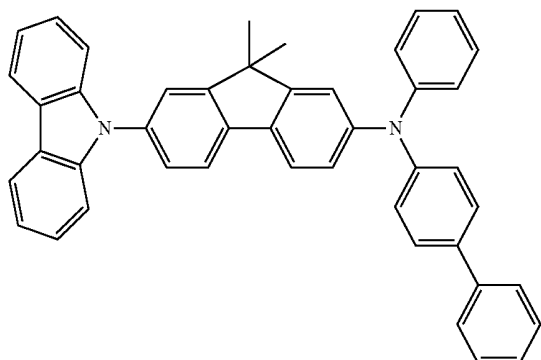


HT18

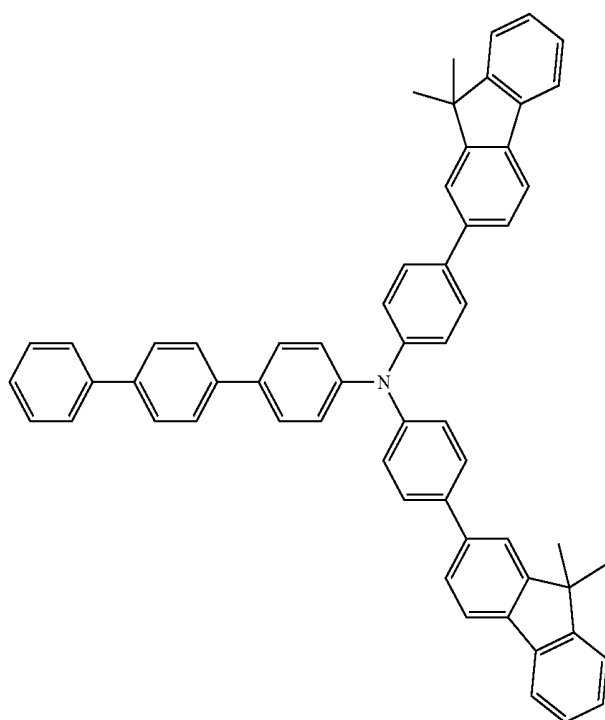


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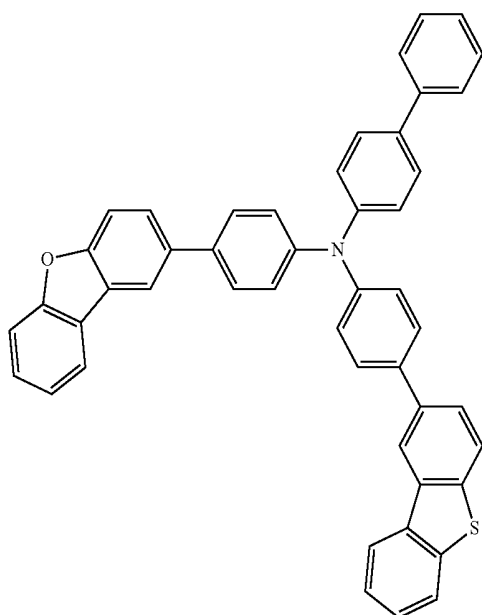
HT19



HT20

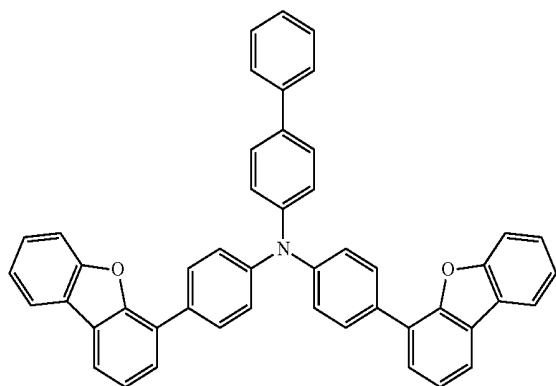


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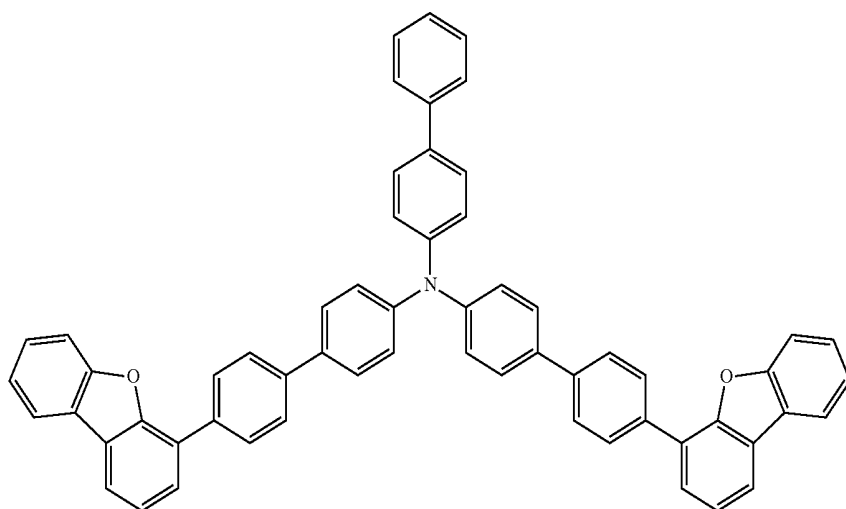


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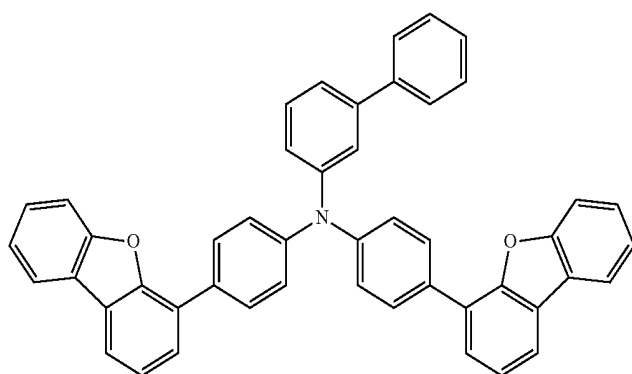
HT22



HT23

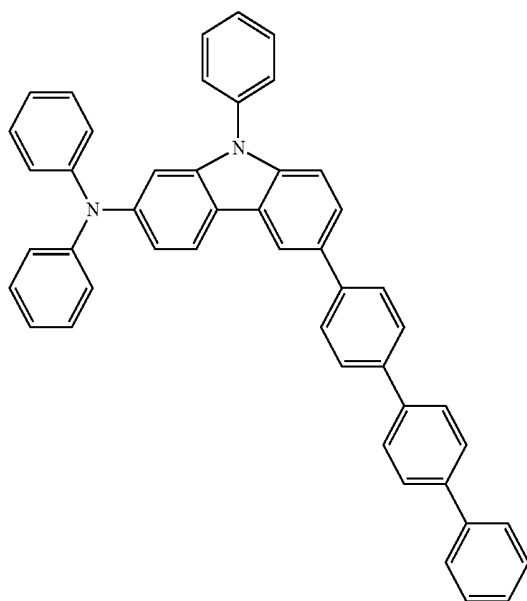


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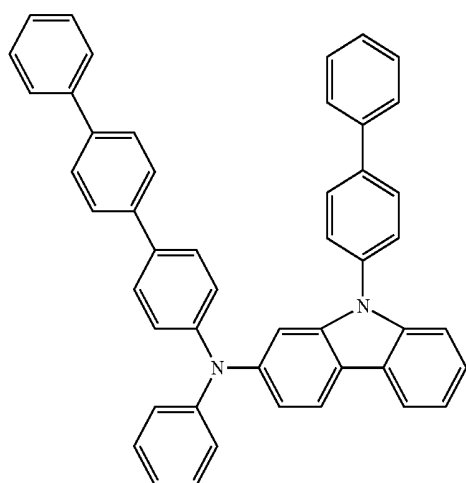


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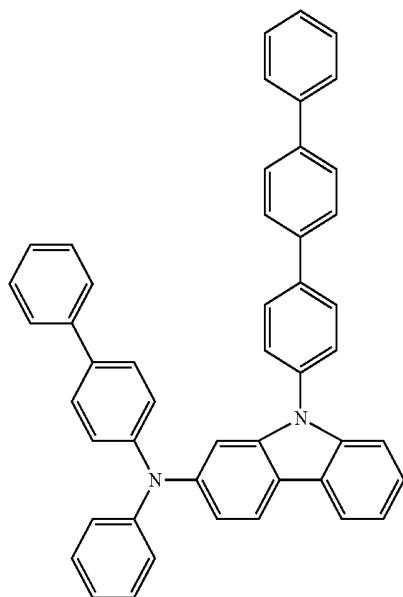
HT25



HT26

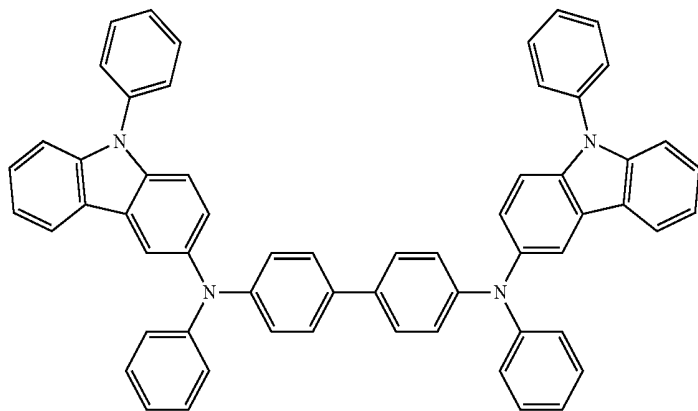


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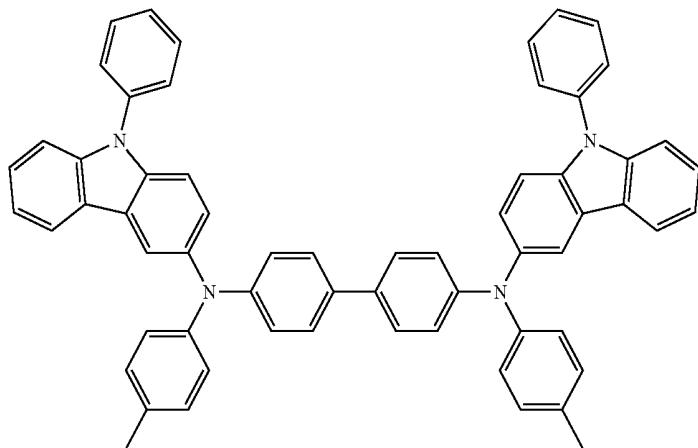


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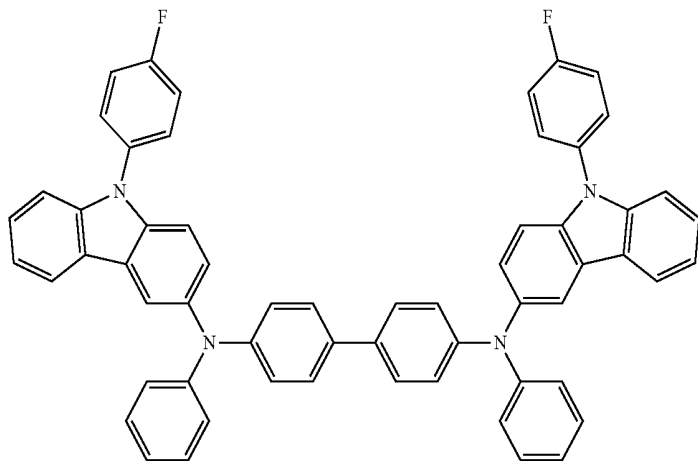
HT28



HT29

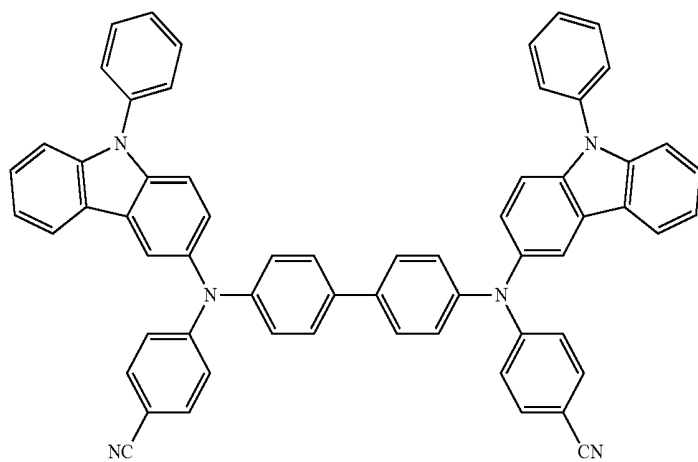


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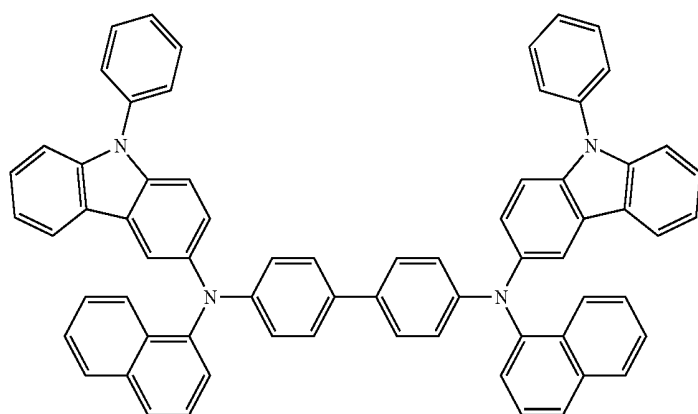


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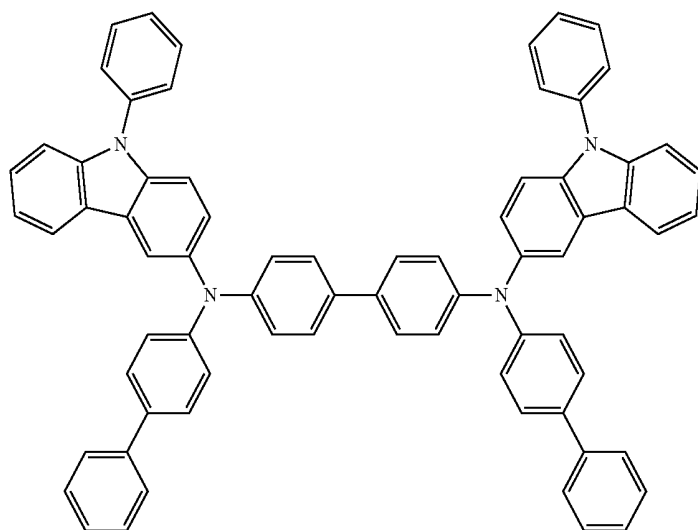
HT31



HT32

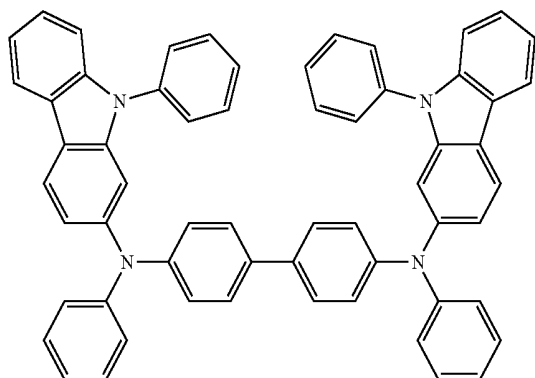


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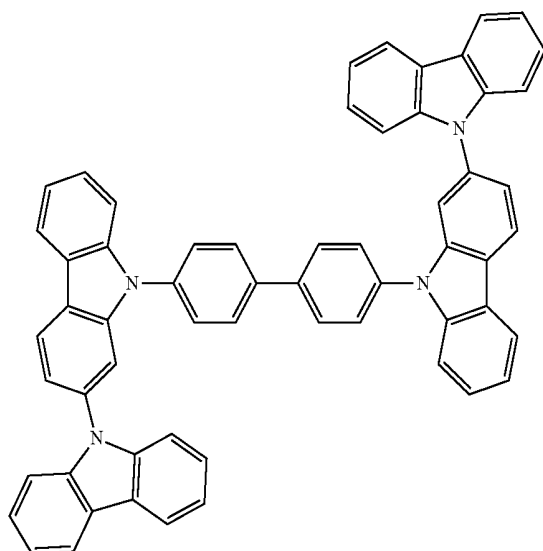


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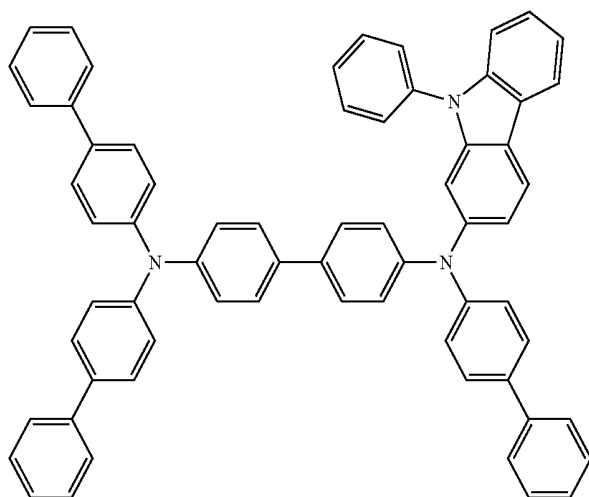
HT34



HT35

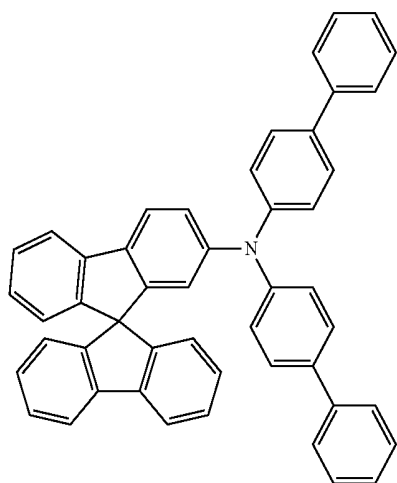


HT36

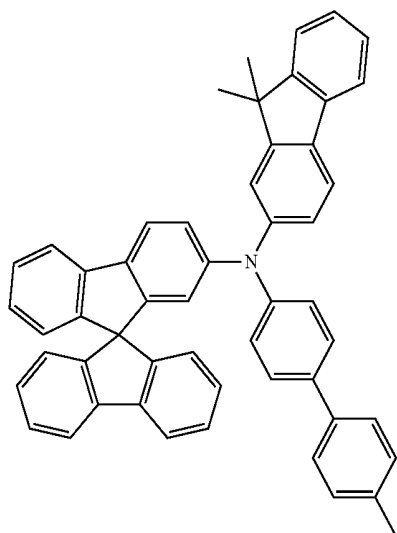


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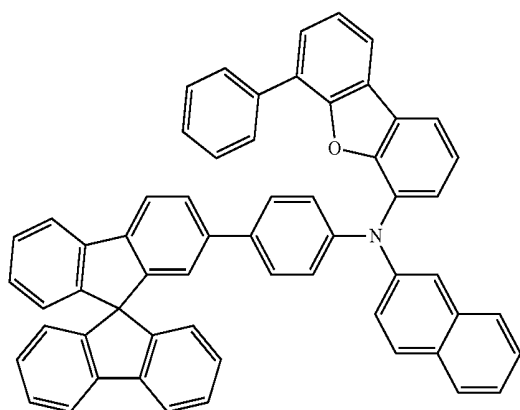
HT37



HT38



HT39



[0188] A thickness of the hole transport region may be in a range of about 100 Å to about 10,000 Å, for example, about 100 Å to about 1,000 Å. When the hole transport region includes at least one of a hole injection layer and a hole transport layer, a thickness of the hole injection layer may be in a range of about 100 Å to about 9,000 Å, for example, about 100 Å to about 1,000 Å, and a thickness of the hole transport layer may be in a range of about 50 Å to

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

[0189] The emission auxiliary layer may increase light-emission efficiency by compensating for an optical reso-

nance distance according to the wavelength of light emitted by an emission layer, and the electron blocking layer may block the flow of electrons from an electron transport region. The emission auxiliary layer and the electron blocking layer may include the materials as described above.

[0190] 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.

[0191] The charge-generation material may be, for example, a p-dopant.

[0192] In one embodiment, a lowest unoccupied molecular orbital (LUMO) energy level of the p-dopant may be -3.5 eV or less.

[0193] 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.

[0194] For example, the p-dopant may include at least one selected from:

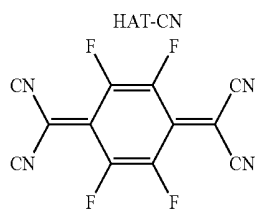
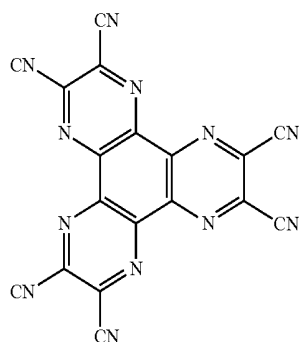
[0195] a quinone derivative, such as tetracyanoquinodimethane (TCNQ) or 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F4-TCNQ);

[0196] a metal oxide, such as tungsten oxide or molybdenum oxide;

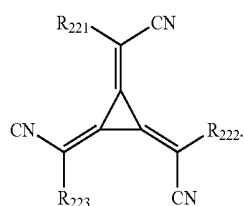
[0197] 1,4,5,8,9,11-hexaazatriphenylene-hexacarbonitrile (HAT-CN); and

[0198] a compound represented by Formula 221 below:

[0199] but embodiments of the present disclosure are not limited thereto:



F4-TCNQ



Formula 221

[0200] In Formula 221,

[0201] 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 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, and 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 $-I$.

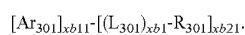
[0202] When the organic light-emitting device **10** is a full-color organic light-emitting device, the emission layer may be patterned into a red emission layer, a green emission layer, or a blue emission layer, according to a sub-pixel. In one or more embodiments, the emission layer may have a stacked structure of two or more layers selected from a red emission layer, a green emission layer, and a blue emission layer, in which the two or more layers contact each other or are separated from each other. In one or more embodiments, the emission layer may include two or more materials selected from a red light-emitting material, a green light-emitting material, and a blue light-emitting material, in which the two or more materials are mixed with each other in a single layer to emit white light.

[0203] 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.

[0204] An amount of the dopant in the emission layer may be, in general, in a range of about 0.01 parts by weight to about 15 parts by weight based on 100 parts by weight of the host, but embodiments of the present disclosure are not limited thereto.

[0205] A thickness of the emission layer may be in a range of about 100 Å to about 1,000 Å, for example, about 200 Å to about 600 Å. When the thickness of the emission layer is within this range, excellent light-emission characteristics may be obtained without a substantial increase in driving voltage.

[0206] In one or more embodiments, the host may include a compound represented by Formula 301:



Formula 301

[0207] In Formula 301,

[0208] 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,

[0209] $xb11$ may be 1, 2, or 3; and

[0210] 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,

[0211] $xb1$ may be an integer from 0 to 5,

[0212] 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 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}),

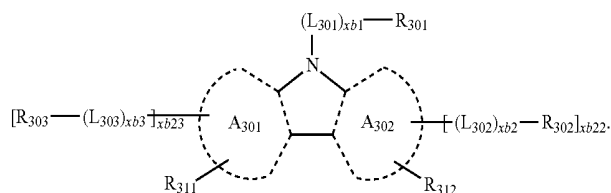
pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, and a dibenzothiophene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro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

[0218] 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, but embodiments of the present disclosure are not limited thereto.

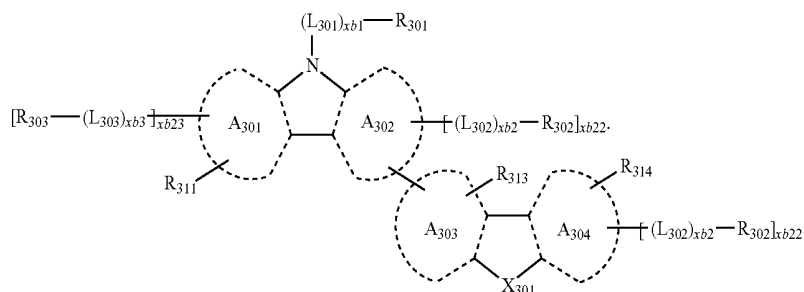
[0219] When $xb1$ in Formula 301 is two or more, two or more $Ar_{301}(s)$ may be linked via a single bond.

[0220] 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



[0213] $xb21$ may be an integer from 1 to 5, and

[0214] 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.

[0215] In one embodiment, in Formula 301, Ar_{301} may be selected from:

[0216] 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;

[0217] 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

[0221] In Formulae 301-1 and 301-2,

[0222] 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, dibenzocarbazole group, a furan group, a benzofuran group, a dibenzofuran group, a naphthofuran group, a benzonaphthofuran group, dinaphthofuran group, a thiophene group, a benzothiophene group, a dibenzothiophene group, a naphthothiophene group, a benzonaphthothiophene group, and a dinaphthothiophene group,

[0223] X_{301} is O, S, or N-[(L_{304})xb4- R_{304}],

[0224] 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 $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, $-\text{N}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{B}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{C}(=\text{O})(\text{Q}_{31})$, $-\text{S}(=\text{O})_2(\text{Q}_{31})$, and $-\text{P}(=\text{O})(\text{Q}_3\text{O}(\text{Q}_{32}))$.

[0225] $\text{xb}22$ and $\text{xb}23$ may each independently be 0, 1, or 2,

[0226] L_{301} , $\text{xb}1$, R_{301} , and Q_{31} to Q_{33} are the same as described above,

[0227] L_{302} to L_{304} may each independently be the same as described in connection with L_{301} ,

[0228] $\text{xb}2$ to $\text{xb}4$ may each independently be the same as described in connection with $\text{xb}1$, and

[0229] R_{302} to R_{304} may each independently be the same as described in connection with R_{301} .

[0230] For example, L_{301} to L_{304} in Formulae 301, 301-1, and 301-2 may each independently be selected from:

[0231] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylenylene group, a fluoranthenylenylene group, a triphenylenylene group, a pyrenylene group, a chrysénylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylenylene group, a pentacenylenylene group, a thiophenylenylene group, a furanylenylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylenylene group, a benzothiophenylenylene group, a dibenzofuranylenylene group, a dibenzothiophenylenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, a pyridinylenylene group, an imidazolylenylene group, a pyrazolylenylene group, a thiazolylenylene group, an isothiazolylenylene group, an oxazolylenylene group, an isoxazolylenylene group, a thiadiazolylenylene group, an oxadiazolylenylene group, a pyrazinylenylene group, a pyrimidinylenylene group, a pyridazinylenylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quiazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylenylene group, an isobenzothiazolylenylene group, a benzoxazolylenylene group, an isobenzoxazolylenylene group, a triazolylenylene group, a tetrazolylenylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolylenylene group;

[0232] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylenylene group, a fluoranthenylenylene group, a triphenylenylene group, a pyrenylene group, a chrysénylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylenylene group, a pentacenylenylene group, a thiophenylenylene group, a furanylenylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylenylene group, a benzothiophenylenylene group, a dibenzofuranylenylene group, a dibenzothiophenylenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, a pyridinylenylene group, an imidazolylenylene group, a pyrazolylenylene group, a thiazolylenylene group, an isothiazolylenylene group, an oxazolylenylene group, an isoxazolylenylene group, a thiadiazolylenylene group, an oxadiazolylenylene group, a pyrazinylenylene group, a pyrimidinylenylene group, a pyridazinylenylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quiazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylenylene group, an isobenzothiazolylenylene group, a benzoxazolylenylene group, an isobenzoxazolylenylene group, a triazolylenylene group, a tetra-

linylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylenylene group, an isobenzothiazolylenylene group, a benzoxazolylenylene group, an isobenzoxazolylenylene group, a triazolylenylene group, a tetrazolylenylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolylenylene group, each substituted with at least one selected from deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a 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 chrysényl group, a perylenyl group, a pentaphenyl group, a hexacenylenylene group, a pentacenylenylene group, a thiophenyl group, a furanyl group, a carbazoyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazoyl group, a dibenzocarbazoyl 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 quiazolinyl 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 azacarbazoyl group, $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, $-\text{N}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{B}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{C}(=\text{O})(\text{Q}_{31})$, $-\text{S}(=\text{O})_2(\text{Q}_{31})$, and $-\text{P}(=\text{O})(\text{Q}_3\text{O}(\text{Q}_{32}))$, and

[0233] Q_{31} to Q_{33} may be the same as described above.

[0234] In one embodiment, R_{301} to R_{304} in Formulae 301, 301-1 and 301-2 may each independently be selected from:

[0235] 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 chrysényl group, a perylenyl group, a pentaphenyl group, a hexacenylenylene group, a pentacenylenylene group, a thiophenyl group, a furanyl group, a carbazoyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazoyl group, a dibenzocarbazoyl 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 quiazolinyl 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 tetra-

zoyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group; and

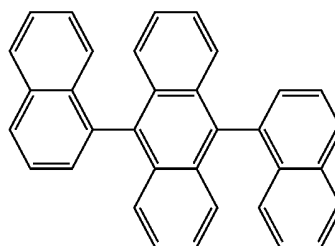
[0236] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, 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 quinoxalinyl 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 quinoxalinyl 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

[0237] Q_{31} and Q_{33} may be the same as described above.

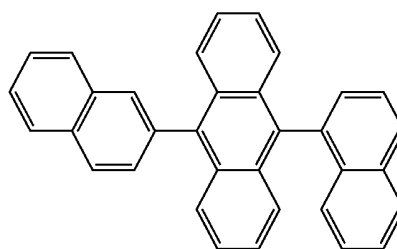
[0238] In one or more embodiments, the host may include an alkaline earth metal complex. For example, the host may be selected from a Be complex (for example, Compound H55), a Mg complex, and a Zn complex.

[0239] The host may include at least one selected from 9,10-di(2-naphthyl)anthracene (ADN), 2-methyl-9,10-bis

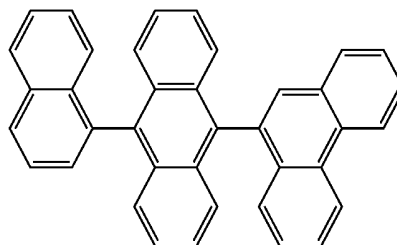
(naphthalen-2-yl)anthracene (MADN), 9,10-di(2-naphthyl)-2-t-butyl-anthracene (TBADN), 4,4'-bis(N-carbazolyl)-1,1'-biphenyl (CBP), 1,3-di-9-carbazolylbenzene (mCP), 1,3,5-tri(carbazol-9-yl)benzene (TCP), and Compounds H1 to H55, but embodiments of the present disclosure are not limited thereto:



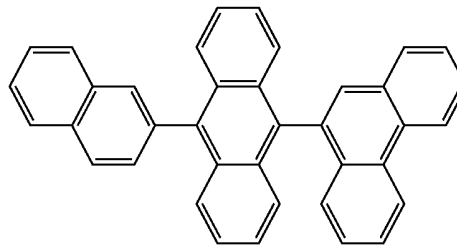
H1



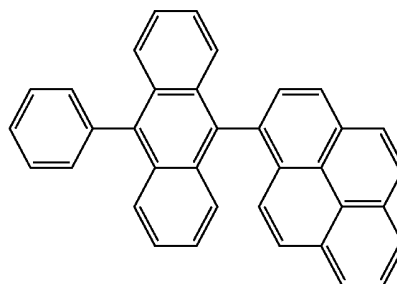
H2



H3

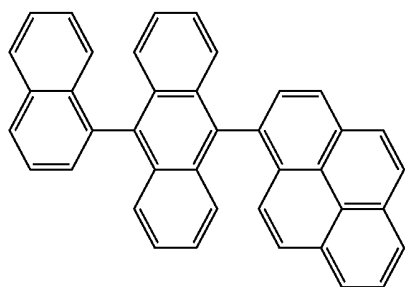


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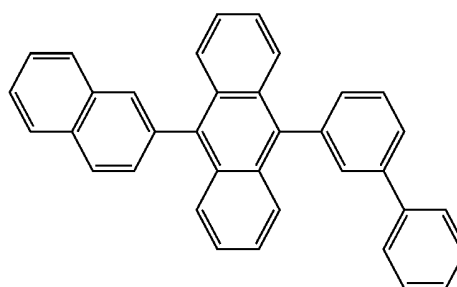
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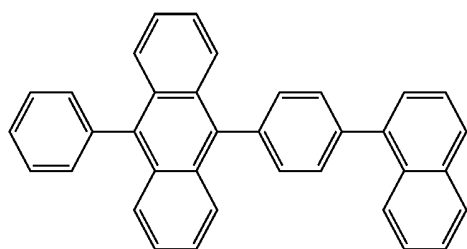


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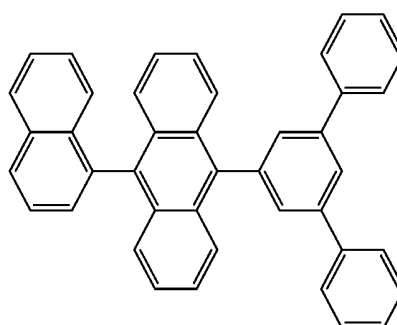
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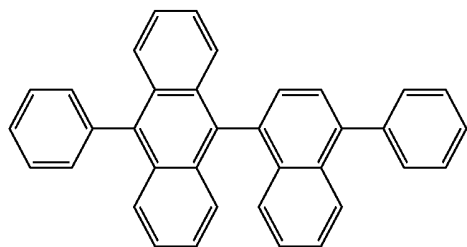
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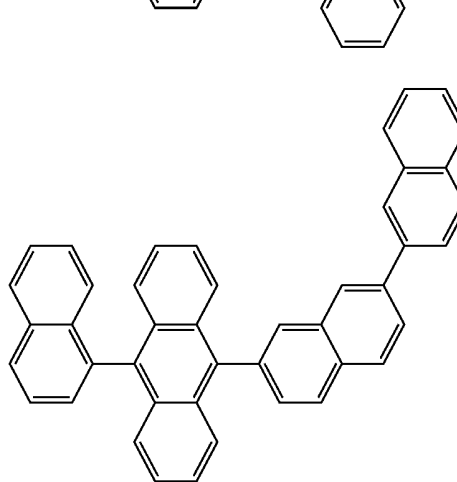
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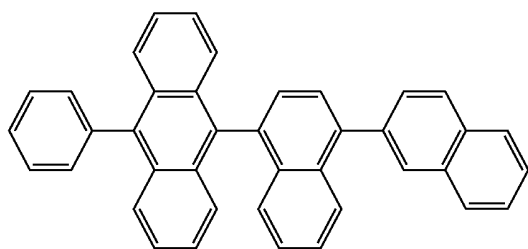
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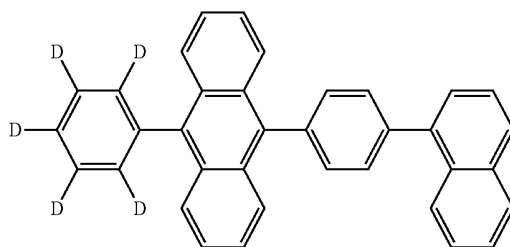
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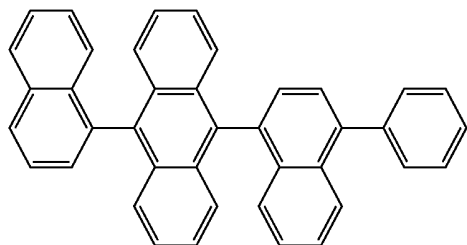
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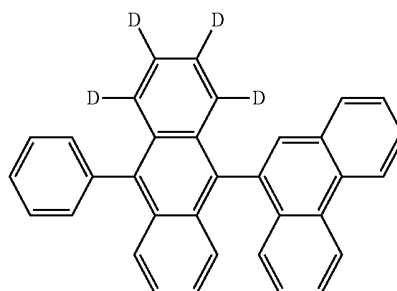
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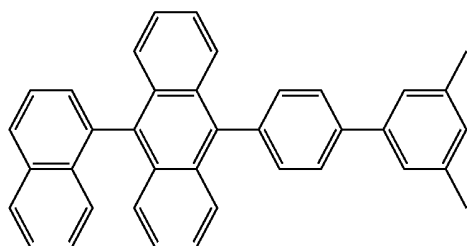
H15



H10



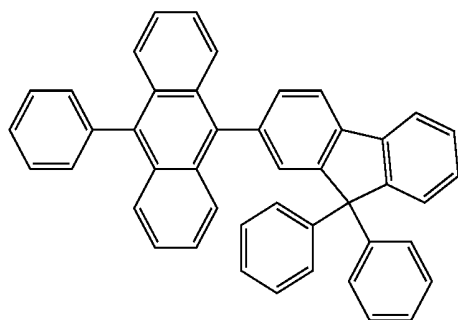
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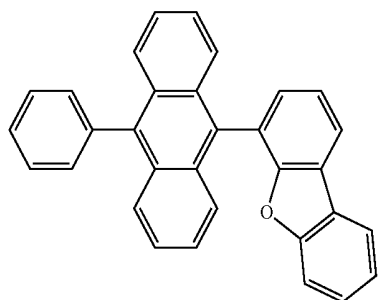
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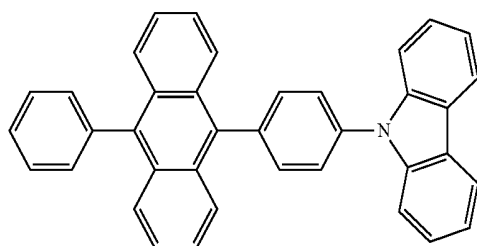
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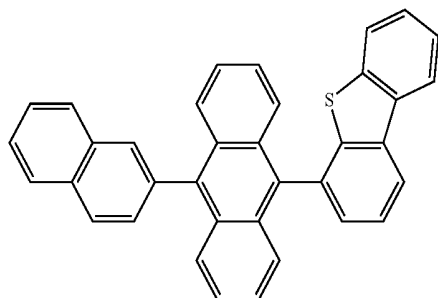
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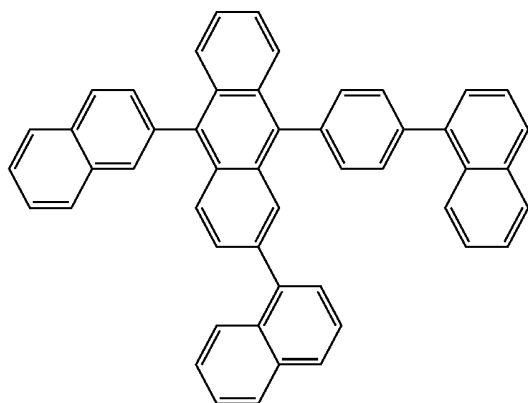
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H20

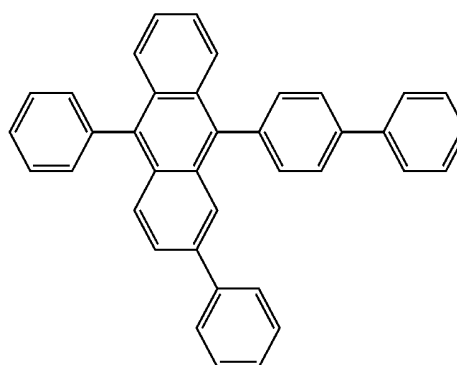


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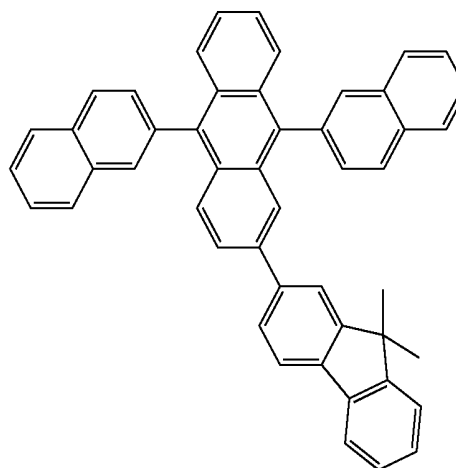


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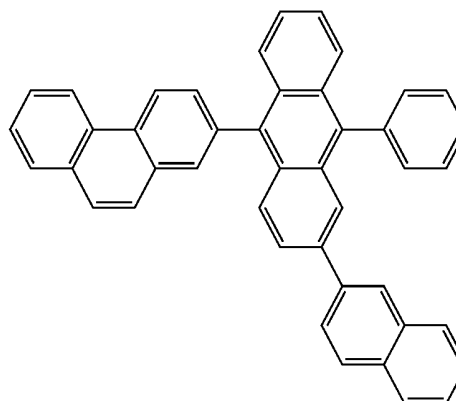
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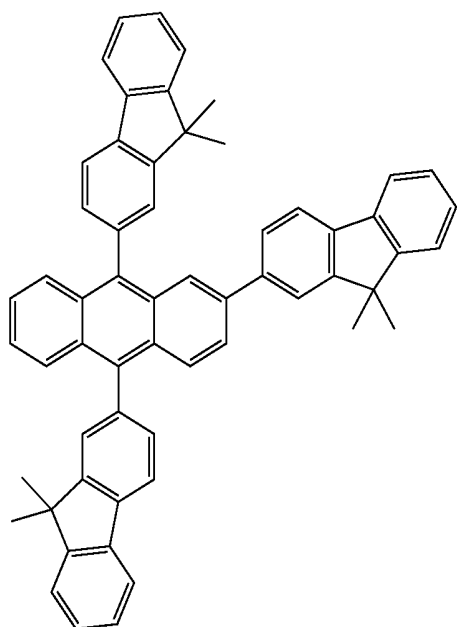
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H24

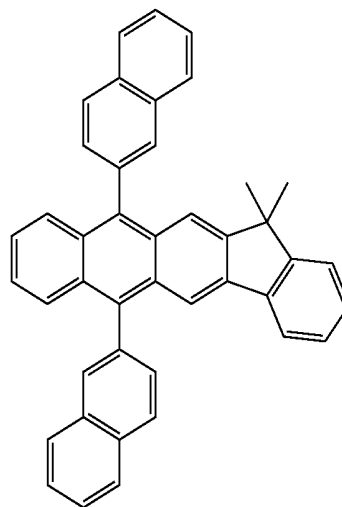


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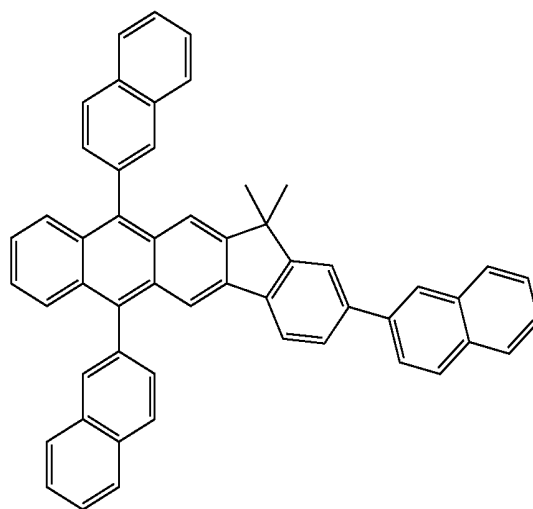
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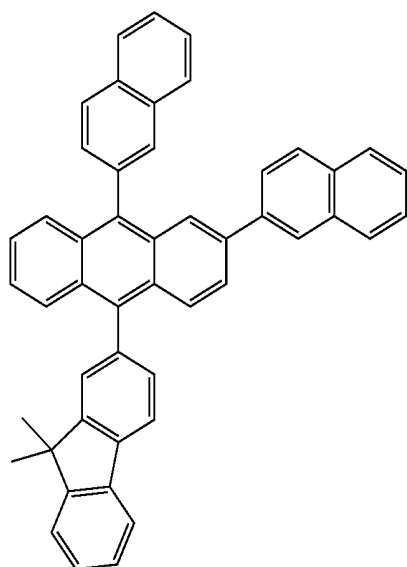


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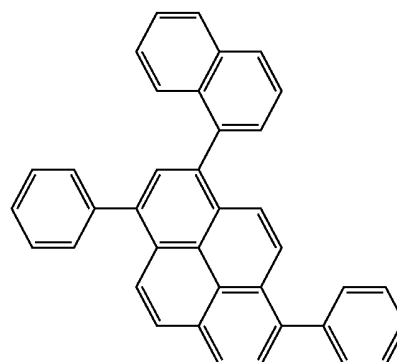
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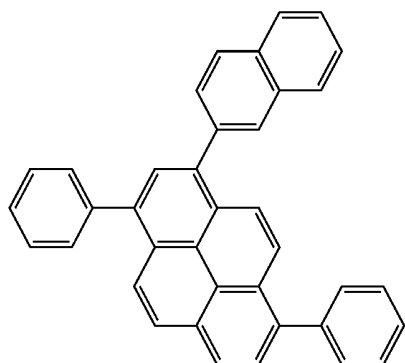
H26



H29

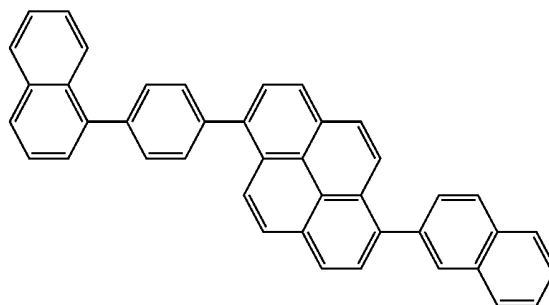


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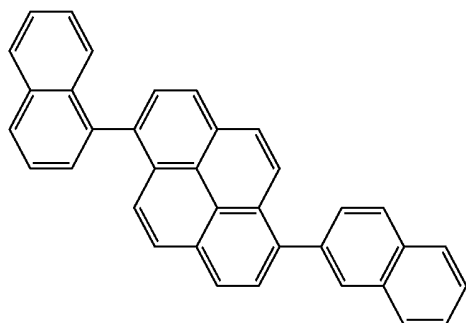
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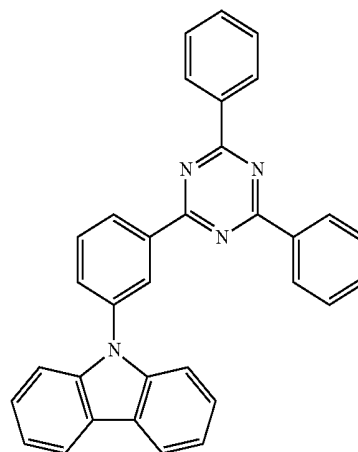


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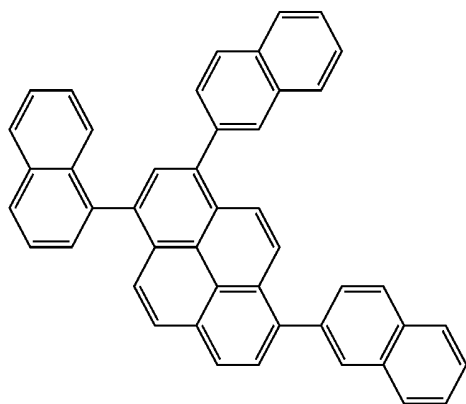
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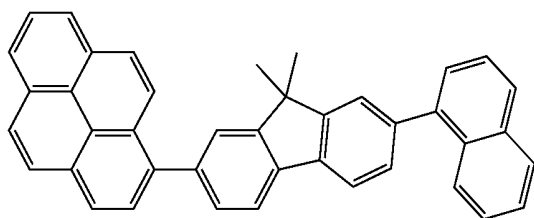
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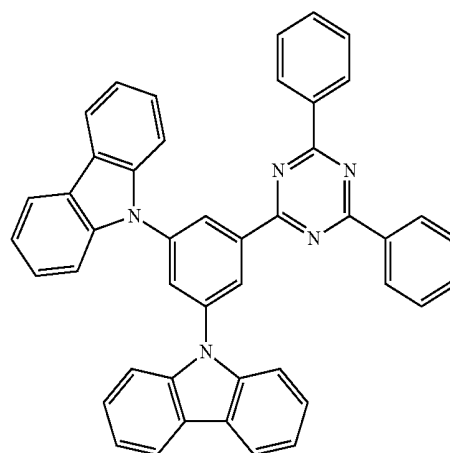
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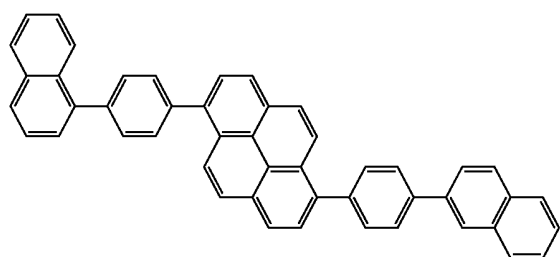
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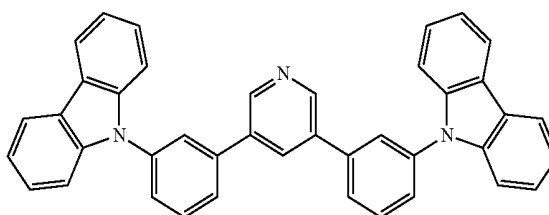
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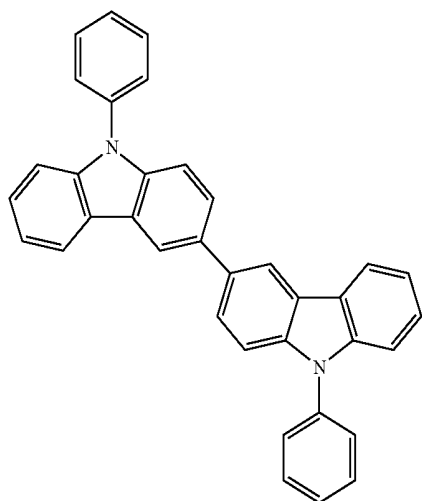
H37



H38

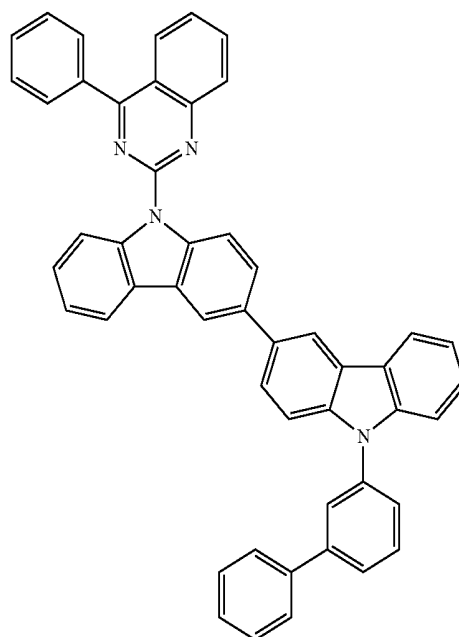


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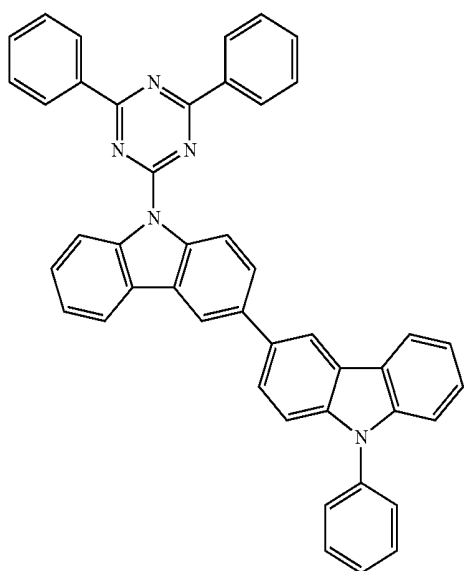


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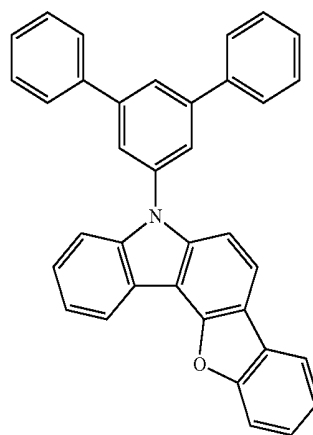
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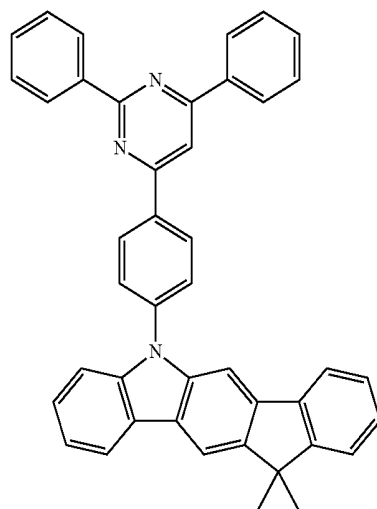
H41



H40

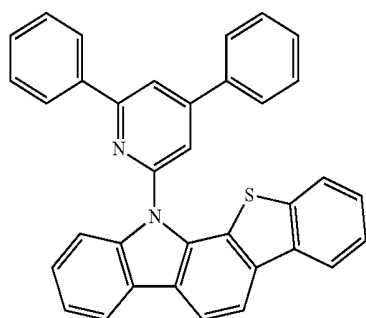


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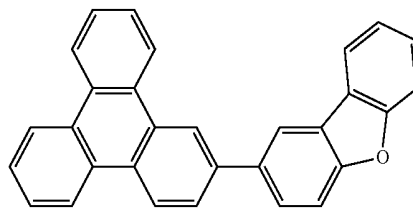
H43

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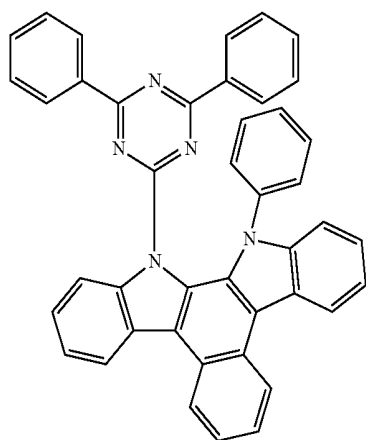


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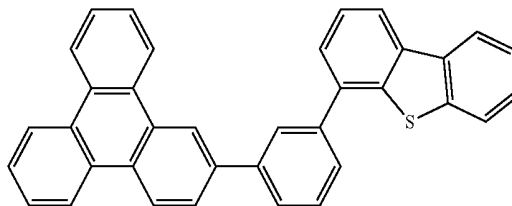
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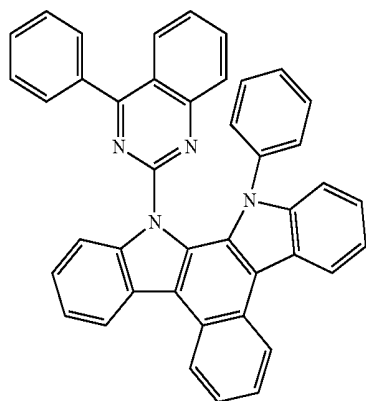
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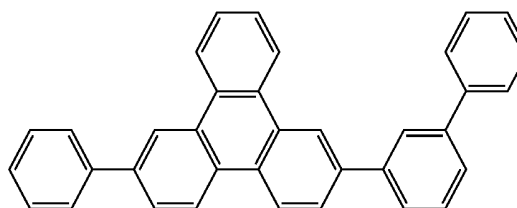
H45



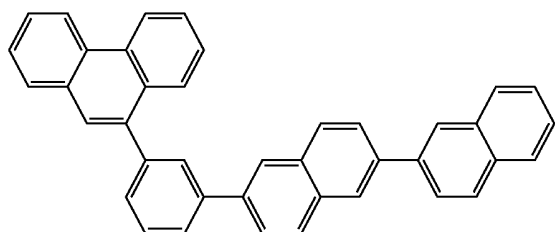
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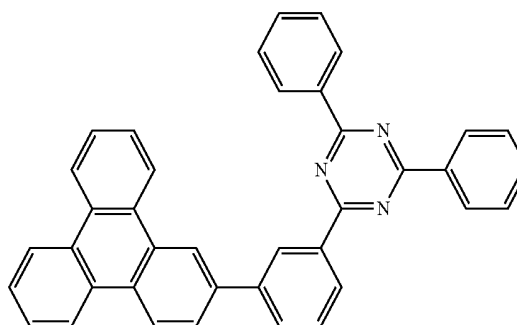
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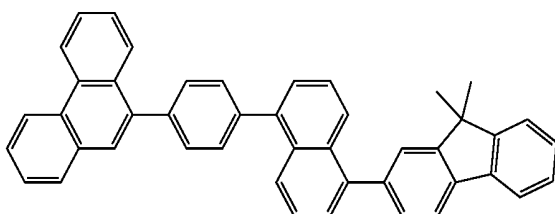
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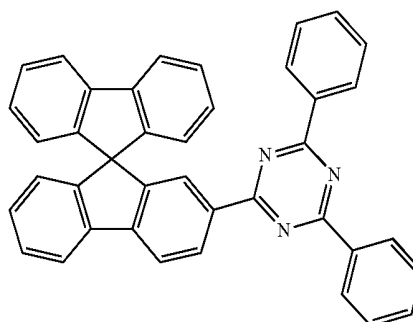
H47



H52

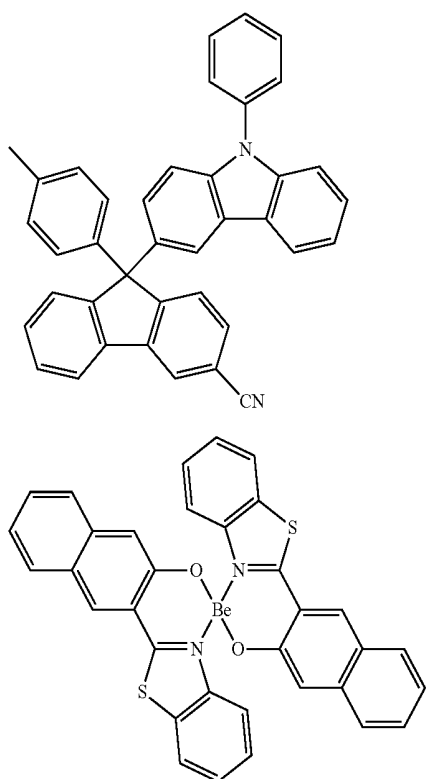


H48



H53

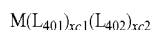
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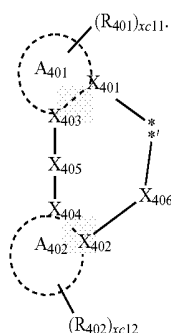
H54

H55

[0240] The phosphorescent dopant may include an organometallic complex represented by Formula 401 below:



Formula 401



Formula 402

[0241] In Formulae 401 and 402,

[0242] 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),

[0243] 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,

[0244] 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,

[0245] X_{401} to X_{404} may each independently be nitrogen or carbon,

[0246] 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,

[0247] A_{401} and A_{402} may each independently be selected from a C_5 - C_{60} carbocyclic group or a C_1 - C_{60} heterocyclic group,

[0248] X_{405} may be a single bond, $^*O^*$, $^*S^*$, $^*C(=O)^*$, $^*N(Q_{411})^*$, $^*C(Q_{411})(Q_{412})^*$, $^*C(Q_{411})=C(Q_{412})^*$, $^*C(Q_{411})^*$, or $^*C(Q_{411})=^*$, and Q_{411} and Q_{412} are 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,

[0249] X_{406} may be a single bond, O, or S,

[0250] R_{401} and R_{402} may each independently be selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1 - C_{20} alkyl group, a substituted or unsubstituted C_1 - C_{20} alkoxy group, a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted 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 $-P(=O)(Q_{401})(Q_{402})$, and Q_{401} to Q_{403} may each independently be selected from a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a C_6 - C_{20} aryl group, and a C_1 - C_{20} heteroaryl group,

[0251] $xc1$ and $xc2$ may each independently be an integer from 0 to 10, and

[0252] $*$ and * in Formula 402 each indicate a binding site to M in Formula 401.

[0253] In one embodiment, 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.

[0254] 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 (e.g., X_{401} and X_{402} may both be nitrogen).

[0255] In one or more embodiments, R_{401} and R_{402} in Formula 402 may each independently be selected from:

[0256] hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino

group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, and a C₁-C₂₀ alkoxy group;

[0257] a C₁-C₂₀ alkyl group, and a C₁-C₂₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a phenyl group, a naphthyl group, a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, and a norbornenyl group;

[0258] 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;

[0259] a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, 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;

[0260] —Si(Q₄₀₁)(Q₄₀₂)(Q₄₀₃), —N(Q₄₀₁)(Q₄₀₂), —B(Q₄₀₁)(Q₄₀₂), —C(=O)(Q₄₀₁), —S(=O)₂(Q₄₀₁) and —P(=O)(Q₄₀₁)(Q₄₀₂); and

[0261] Q₄₀₁ to Q₄₀₃ may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, and a naphthyl group, but embodiments of the present disclosure are not limited thereto.

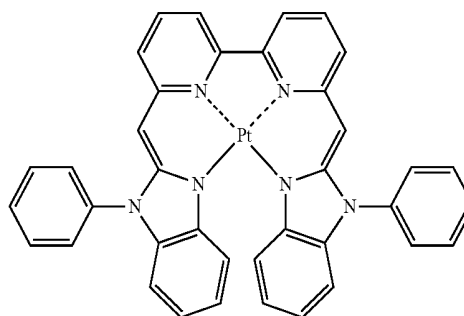
[0262] In one or more embodiments, when xc1 in Formula 401 is two or more, two A₄₀₁(s) in two or more L₄₀₁(s) may optionally be linked via X₄₀₇, which is a linking group, and two A₄₀₂(s) may optionally be linked via X₄₀₈, which is a linking group (see Compounds PD1 to PD4 and PD7). X₄₀₇ and X₄₀₈ may each independently be a single bond, *—O—*, *—S—*, *—C(=O)—*, *—N(Q₄₁₃)*, *—C(Q₄₁₃)(Q₄₁₄)*, or *—C(Q₄₁₃)=C(Q₄₁₄)* (wherein Q₄₁₃ and Q₄₁₄ may each independently be hydrogen, deuterium, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group), but embodiments of the present disclosure are not limited thereto.

[0263] L₄₀₂ in Formula 401 may be a monovalent, divalent, or trivalent organic ligand. For example, L₄₀₂ may be selected from halogen, diketone (for example, acetylacetonate), carboxylic acid (for example, picolinate), —C(=O),

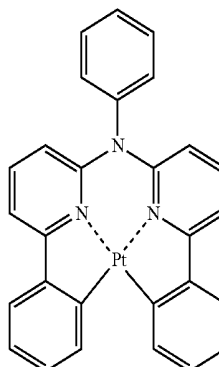
isonitrile, —CN, and phosphorus (for example, phosphine, or phosphite), but embodiments of the present disclosure are not limited thereto.

[0264] 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:

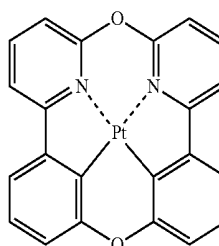
PD1



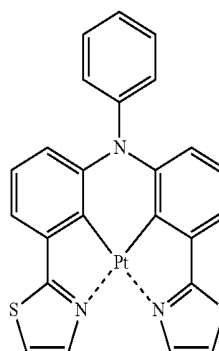
PD2



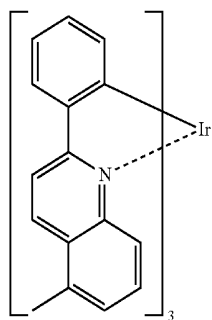
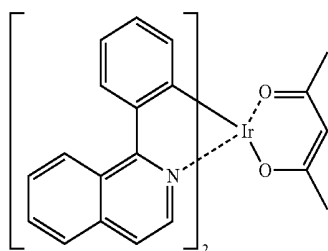
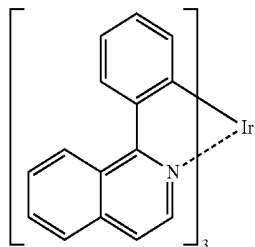
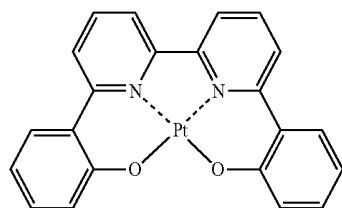
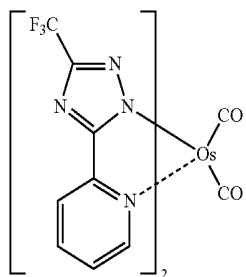
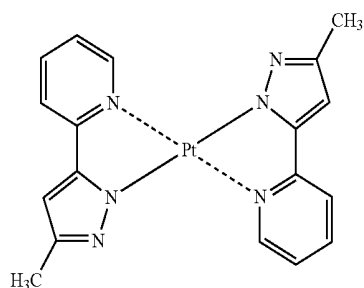
PD3



PD4

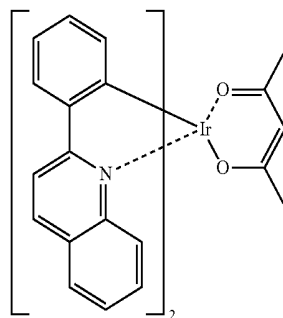


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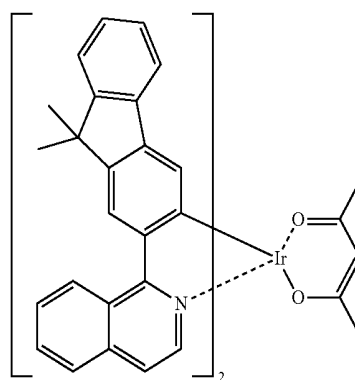
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PD5



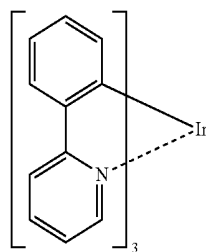
PD11

PD6



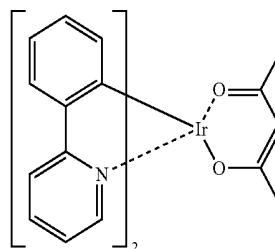
PD12

PD7



PD13

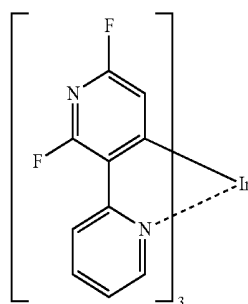
PD8



PD14

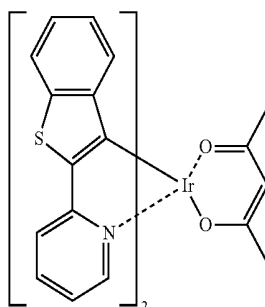
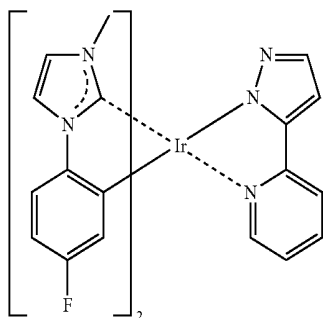
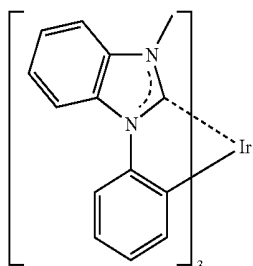
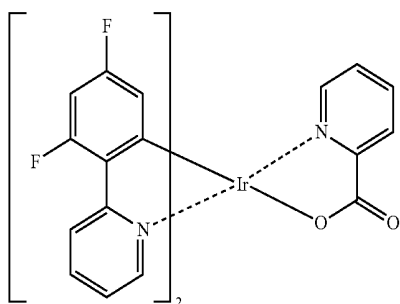
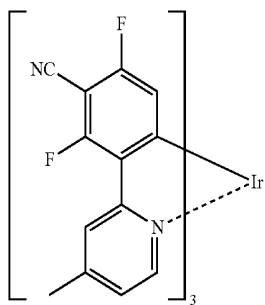
PD9

PD10



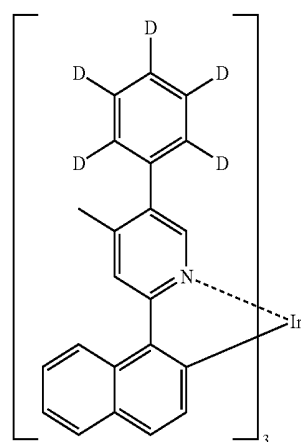
PD15

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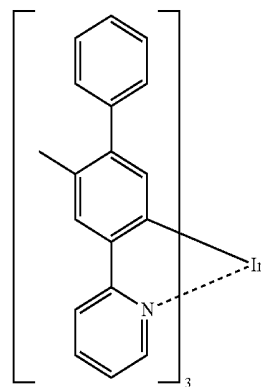
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PD16



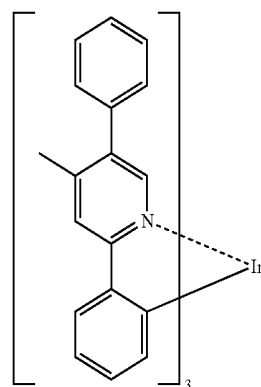
PD21

PD17



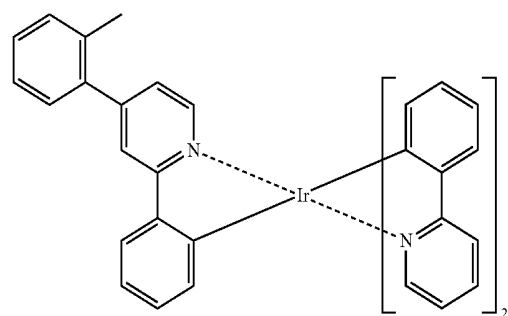
PD22

PD18



PD23

PD19

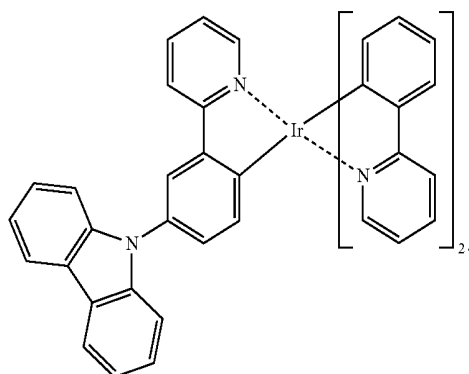


PD24

PD20

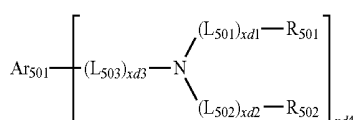
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PD25



[0265] The fluorescent dopant may include an arylamine compound or a styrylamine compound.

[0266] The fluorescent dopant may include a compound represented by Formula 501 below.



Formula 501

[0267] In Formula 501,

[0268] 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,

[0269] 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 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_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0270] $xd1$ to $xd3$ may each independently be an integer of 0 to 3;

[0271] 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,

[0272] $xd4$ may be an integer of 1 to 6.

[0273] In one embodiment, Ar_{501} in Formula 501 may be selected from:

[0274] 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

[0275] a naphthalene group, a heptalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, and an indenophenanthrene group, 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.

[0276] In one or more embodiments, L_{501} to L_{503} in Formula 501 may each independently be selected from:

[0277] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylenylene group, a fluoranthenylenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylenylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylenylene group, a pentacenylenylene group, a thiophenylenylene group, a furanylenylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylenylene group, a benzothiophenylenylene group, a dibenzofuranylenylene group, a dibenzothiophenylenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, a pyridinylenylene group; and

[0278] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylenylene group, a fluoranthenylenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylenylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylenylene group, a pentacenylenylene group, a thiophenylenylene group, a furanylenylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylenylene group, a benzothiophenylenylene group, a dibenzofuranylenylene group, a dibenzothiophenylenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, a pyridinylenylene group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a 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.

[0279] In one or more embodiments, R_{501} and R_{502} in Formula 501 may each independently be selected from:

[0280] 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

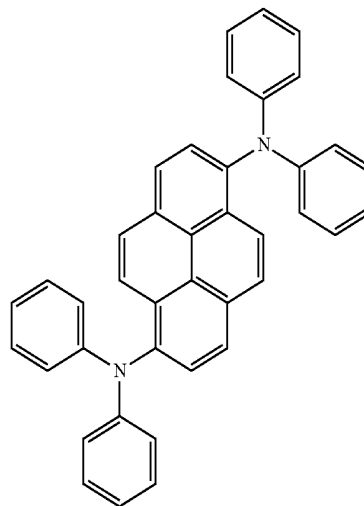
[0281] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, 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

[0282] 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.

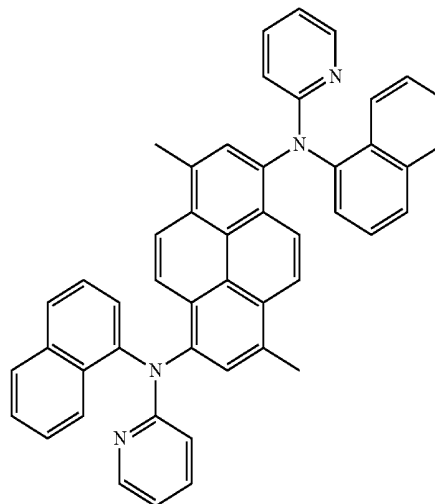
[0283] In one or more embodiments, $xd4$ in Formula 501 may be 2, but embodiments of the present disclosure are not limited thereto.

[0284] For example, the fluorescent dopant may be selected from Compounds FD1 to FD22:

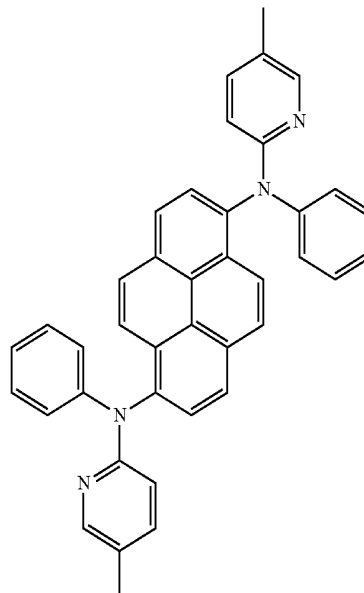
FD1



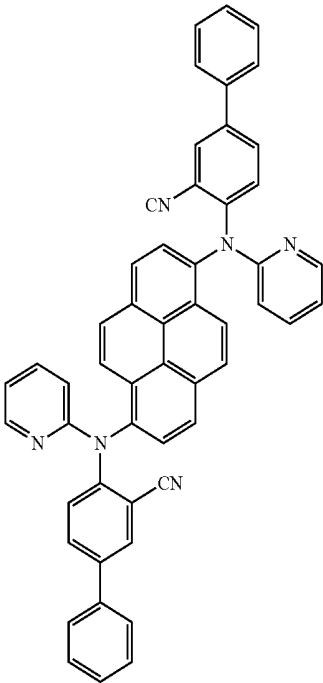
FD2



FD3

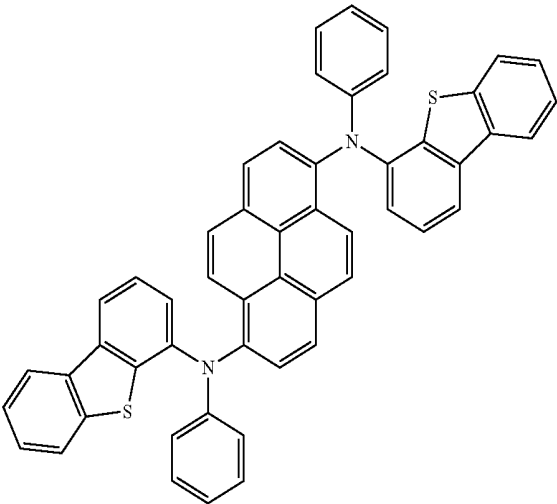


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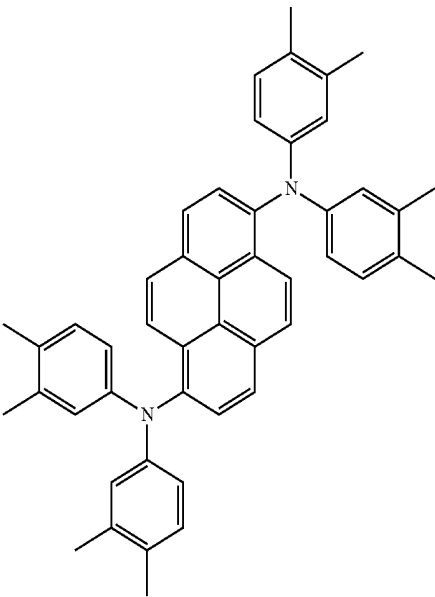
FD4

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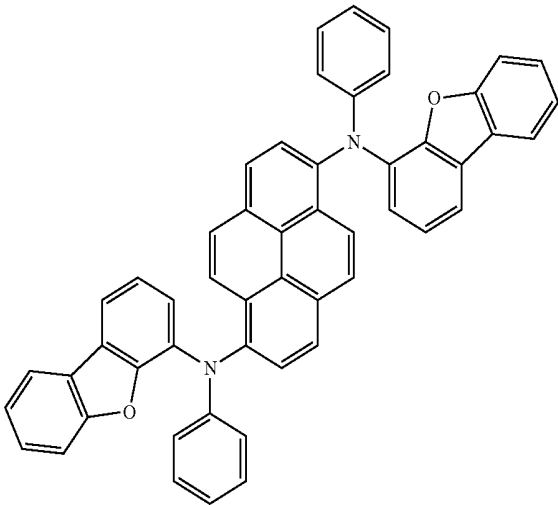


FD6

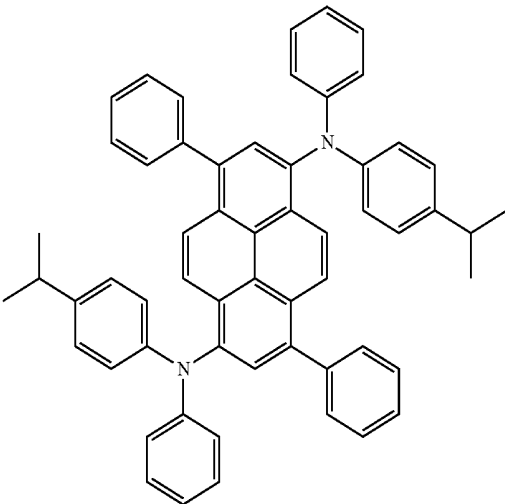
FD7



FD5

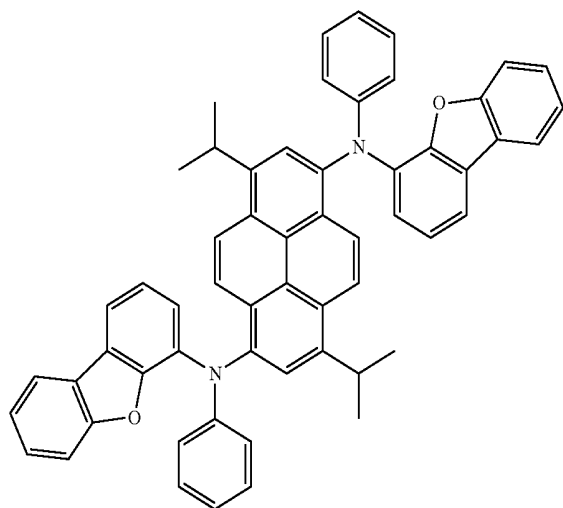


FD8



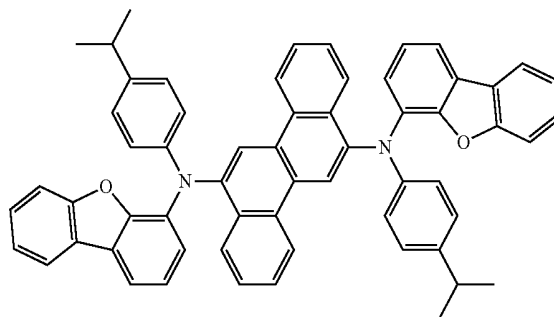
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FD9

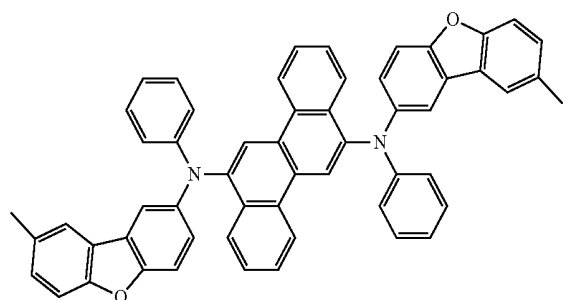


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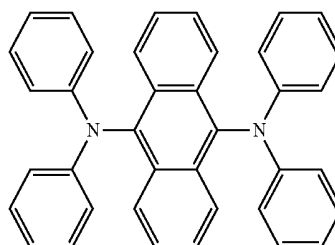
FD13



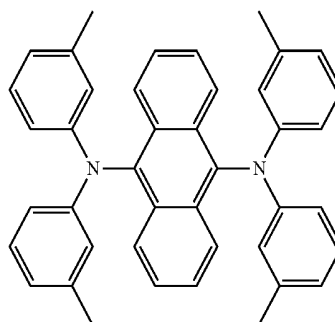
FD10



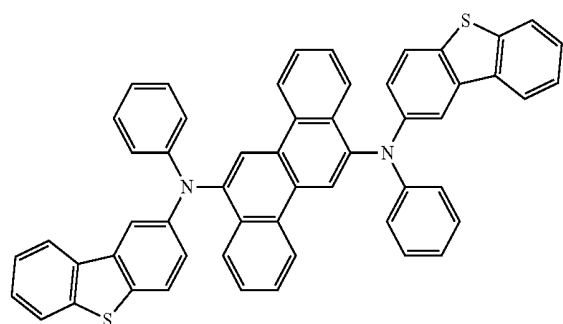
FD14



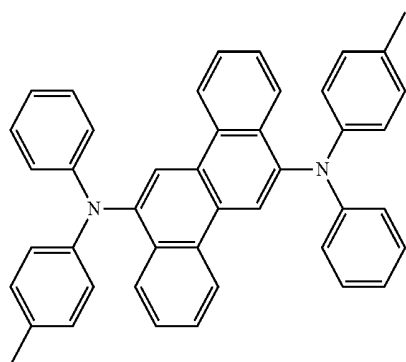
FD15



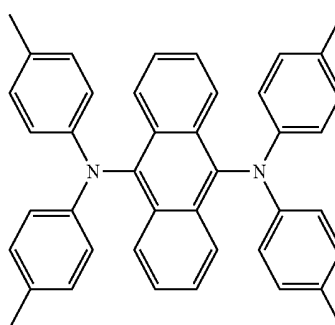
FD11



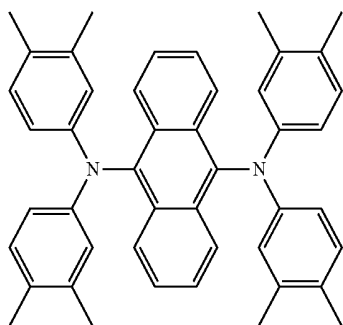
FD12



FD16

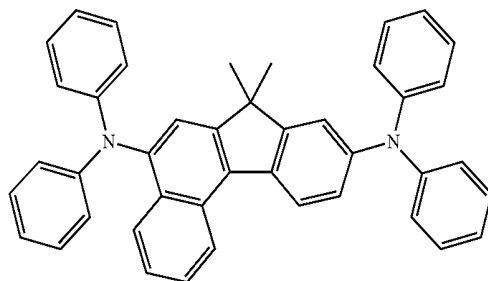


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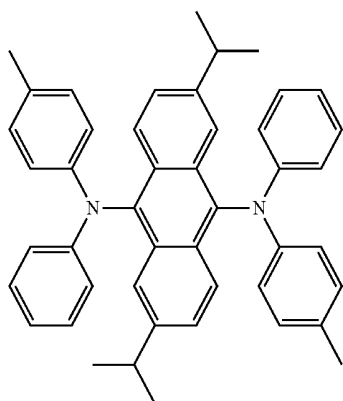
FD17

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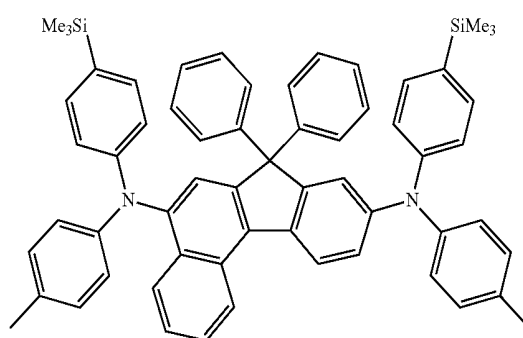


FD20

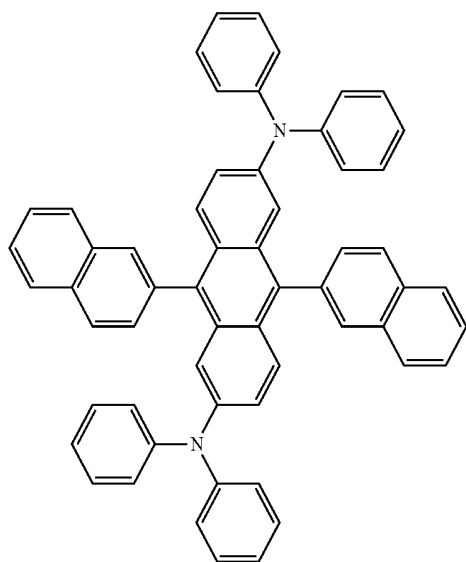
FD18



FD21

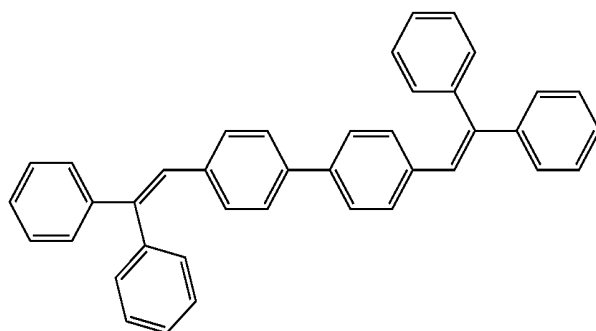


FD19



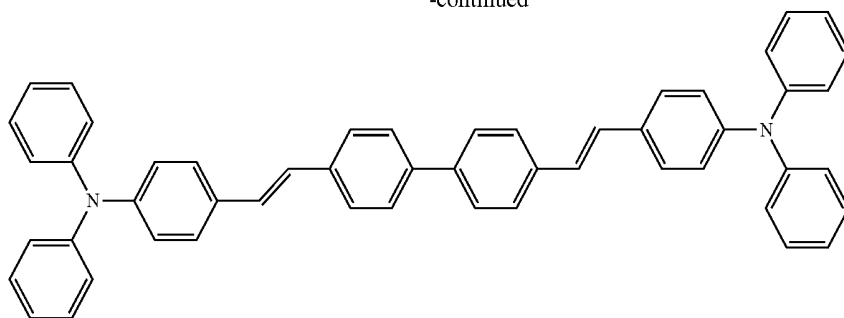
FD22

[0285] 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.

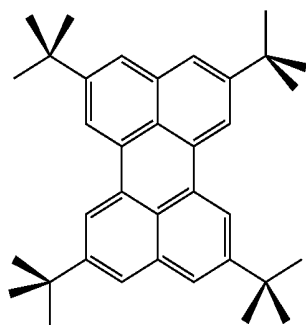


DPVBi

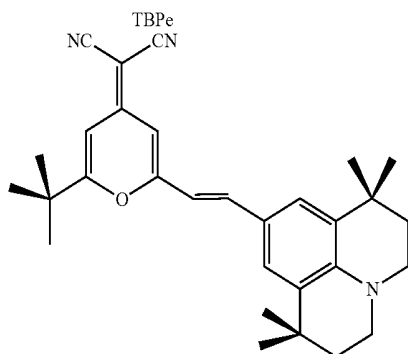
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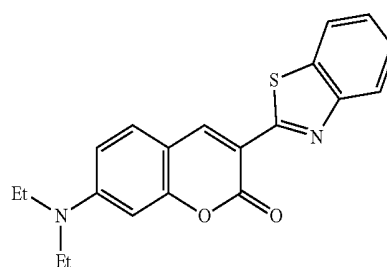
DPAVBi



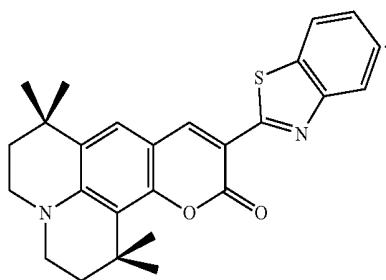
DCM



DCJTb



Coumarin 6



C545T

[0286] 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.

[0287] 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.

[0288] For example, the electron transport region may have an electron transport layer/electron injection layer structure, a hole blocking layer/electron transport layer/electron injection layer structure, an electron control layer/electron transport layer/electron injection layer structure, or a buffer layer/electron transport layer/electron injection layer structure, wherein for each structure, constituting layers are sequentially stacked from an emission layer. However, embodiments of the structure of the electron transport region are not limited thereto.

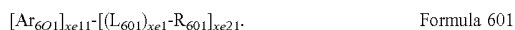
[0289] The electron transport region (for example, a buffer layer, a hole blocking layer, an electron control layer, or an electron transport layer in the electron transport region) may include a metal-free compound containing at least one π electron-depleted nitrogen-containing ring.

[0290] 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.

[0291] 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.

[0292] Examples of the π electron-depleted nitrogen-containing ring include an imidazole, a pyrazole, a thiazole, an isothiazole, an oxazole, an isoxazole, a pyridine, a pyrazine, a pyrimidine, a pyridazine, an indazole, a purine, a quinoline, an isoquinoline, a benzoquinoline, a phthalazine, a naphthyridine, a quinoxaline, a quinazoline, a cinnoline, a phenanthridine, an acridine, a phenanthroline, a phenazine, a benzimidazole, an isobenzothiazole, a benzoxazole, an isobenzoxazole, a triazole, a tetrazole, an oxadiazole, a triazine, thiadiazole, an imidazopyridine, an imidazopyrimidine, and an azacarbazole, but embodiments of the present disclosure are not limited thereto.

[0293] For example, the electron transport region may include a compound represented by Formula 601:



[0294] In Formula 601,

[0295] 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,

[0296] $xe11$ may be 1, 2, or 3,

[0297] L_{601} may be selected from a substituted or unsubstituted C_3 - C_{10} cycloalkylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3 - C_{10} cycloalkenylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6 - C_{60} arylene group, a substituted or unsubstituted C_1 - C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0298] $xe1$ may be an integer from 0 to 5,

[0299] 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 $-P(=O)(Q_{601})(Q_{602})$, and

[0300] 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,

[0301] $xe21$ may be an integer from 1 to 5.

[0302] In one embodiment, at least one of $Ar_{601}(s)$ in the number of $xe11$ and $R_{601}(s)$ in the number of $xe21$ may include the π electron-depleted nitrogen-containing ring.

[0303] In one embodiment, ring Ar_{601} in Formula 601 may be selected from:

[0304] 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 indenanthracene 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;

[0305] a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenanthracene 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

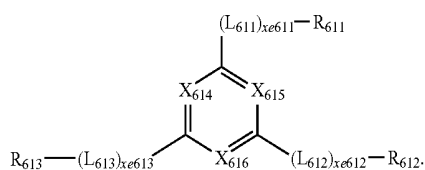
[0306] Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0307] When xe11 in Formula 601 is two or more, two or more Ar₆₀₁(s) may be linked via a single bond.

[0308] In one or more embodiments, Ar₆₀₁ in Formula 601 may be an anthracene group.

[0309] In one or more embodiments, a compound represented by Formula 601 may be represented by Formula 601-1:

Formula 601-1



[0310] In Formula 601-1,

[0311] X₆₁₄ may be N or C(R₆₁₄), X₆₁₅ may be N or C(R₆₁₅), X₆₁₆ may be N or C(R₆₁₆), and at least one selected from X₆₁₄ to X₆₁₆ may be N,

[0312] L₆₁₁ to L₆₁₃ may each independently be the same as described in connection with L₆₀₁,

[0313] xe611 to xe613 may each independently be the same as described in connection with xe1,

[0314] R₆₁₁ to R₆₁₃ may each independently be the same as described in connection with R₆₀₁, and

[0315] R₆₁₄ to R₆₁₆ may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0316] In one embodiment, L₆₀₁ and L₆₁₁ to L₆₁₃ in Formulae 601 and 601-1 may each independently be selected from:

[0317] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylenylene group, a fluoranthenylenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylenylene group, a pentacenylenylene group, a thiophenylenylene group, a furanylenylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylenylene group, a benzothiophenylenylene group, a benzozofuranylenylene group, a dibenzothiophenylenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, a pyridinylenylene group, an imidazolylenylene group, a pyrazolylenylene group, a thiazolylenylene group, an isothiazolylenylene group, an oxazolylenylene group, an isoxazolylenylene group, a thiadiazolylenylene group, an oxadiazolylenylene group, a pyrazinylenylene group, a pyrimidinylenylene group, a pyridazinylenylene group, a triazinylenylene group, a quinolinylenylene group, an isoquinolinylenylene group, a benzoquinolinylenylene group, a phthalazinylenylene group, a naphthyridinylenylene group, a quinoxalinylenylene group, a quinazolinylenylene group, a cinnolinylenylene group, a phenanthridinylenylene group, an acridinylenylene group, a phenanthrolinylenylene group, a phenazinylenylene group, a benzimidazolylenylene group, an isobenzothiazolylenylene group, a benzoxazolylenylene group, an isobenzoxazolylenylene group, a

triazolylenylene group, a tetrazolylenylene group, an imidazopyridinylenylene group, an imidazopyrimidinylene group, and an azacarbazolylenylene group; and

[0318] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylenylene group, a fluoranthenylenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylenylene group, a pentacenylenylene group, a thiophenylenylene group, a furanylenylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylenylene group, a benzothiophenylenylene group, a benzozofuranylenylene group, a dibenzothiophenylenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, a pyridinylenylene group, an imidazolylenylene group, a pyrazolylenylene group, a thiazolylenylene group, an isothiazolylenylene group, an oxazolylenylene group, an isoxazolylenylene group, a thiadiazolylenylene group, an oxadiazolylenylene group, a pyrazinylenylene group, a pyrimidinylenylene group, a pyridazinylenylene group, a triazinylenylene group, a quinolinylenylene group, an isoquinolinylenylene group, a benzoquinolinylenylene group, a phthalazinylenylene group, a naphthyridinylenylene group, a quinoxalinylenylene group, a quinazolinylenylene group, a cinnolinylenylene group, a phenanthridinylenylene group, an acridinylenylene group, a phenanthrolinylenylene group, a phenazinylenylene group, a benzimidazolylenylene group, an isobenzothiazolylenylene group, a benzoxazolylenylene group, an isobenzoxazolylenylene group, a triazolylenylene group, a tetrazolylenylene group, an imidazopyridinylenylene group, an imidazopyrimidinylene group, and an azacarbazolylenylene group;

[0319] but embodiments of the present disclosure are not limited thereto.

[0320] In one or more embodiments, xe1 and xe611 to xe613 in Formulae 601 and 601-1 may each independently be 0, 1, or 2.

[0321] 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:

[0322] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl 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;

[0323] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl 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

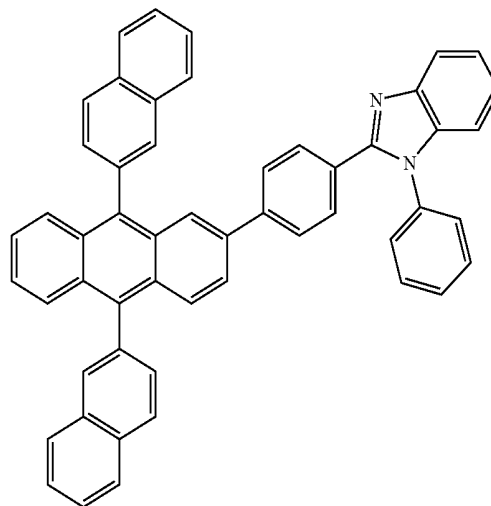
group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl 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;

[0324] $-S(=O)_2(Q_{601})$ and $-P(=O)(Q_{601})(Q_{602})$; and

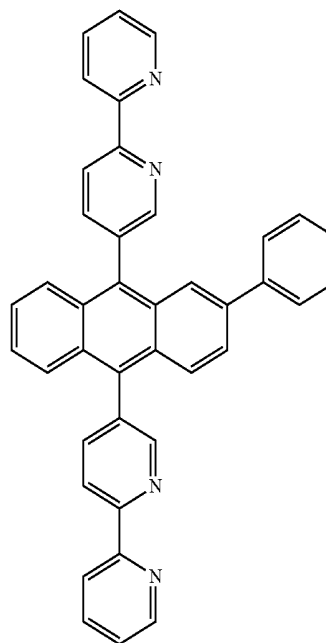
[0325] Q_{601} and Q_{602} may be the same as described above.

[0326] 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

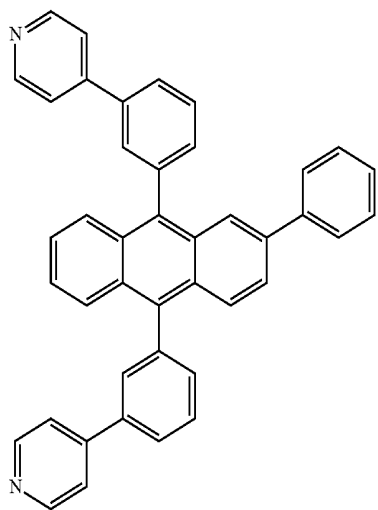


ET2



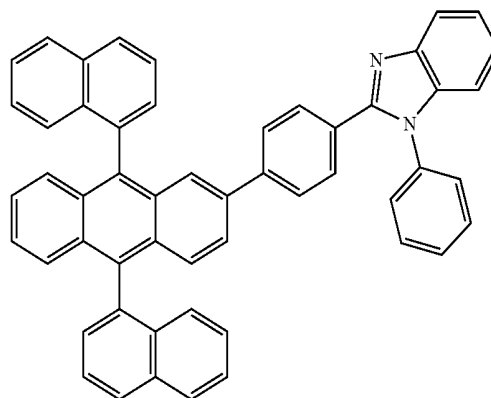
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ET3

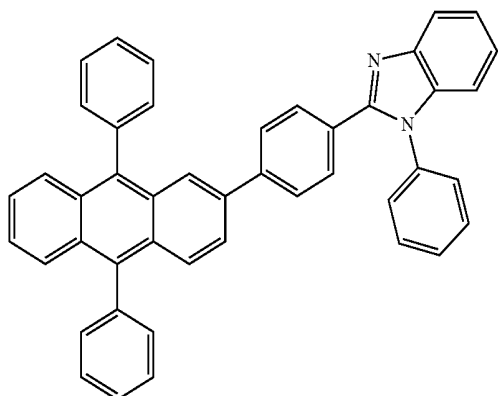


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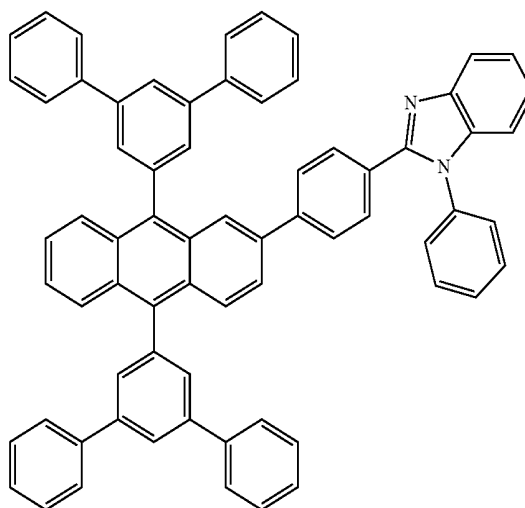
ET6



ET4

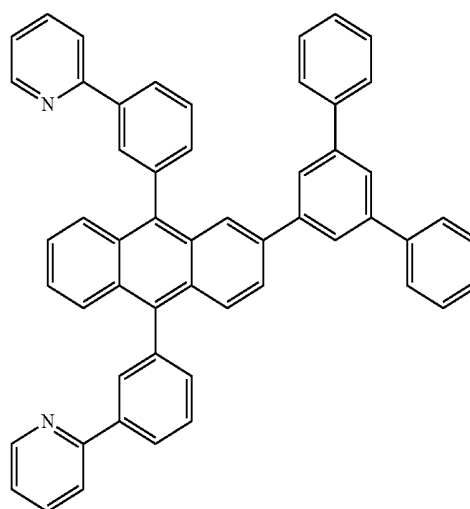
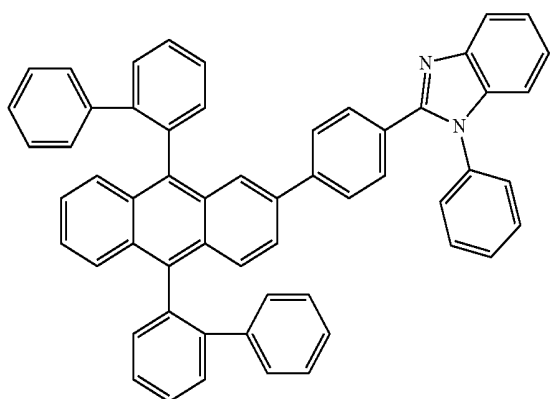


ET7

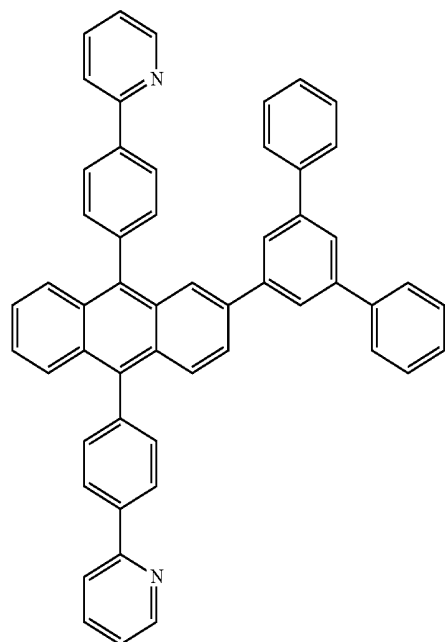


ET8

ET5

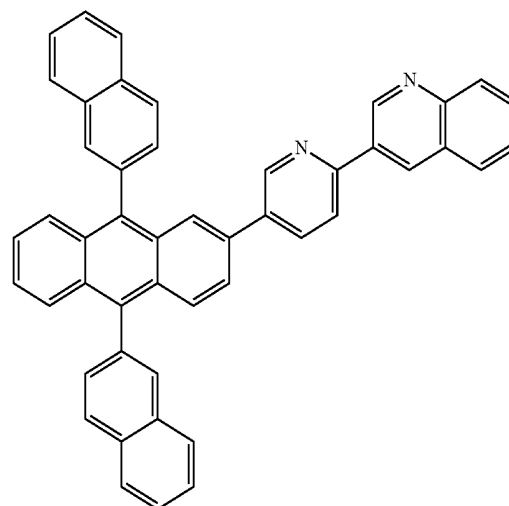


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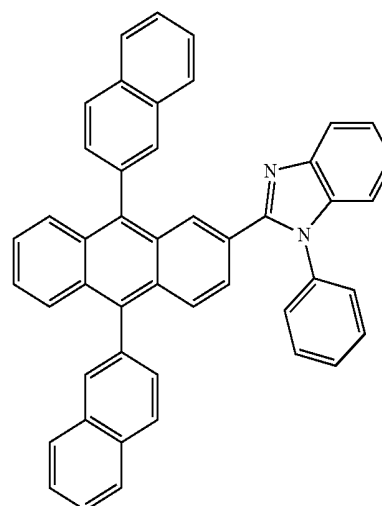
ET9

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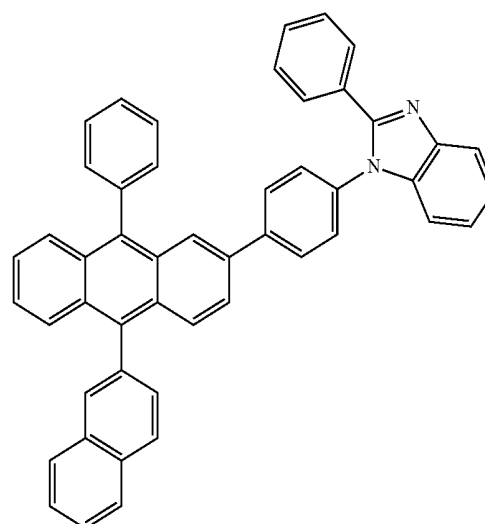
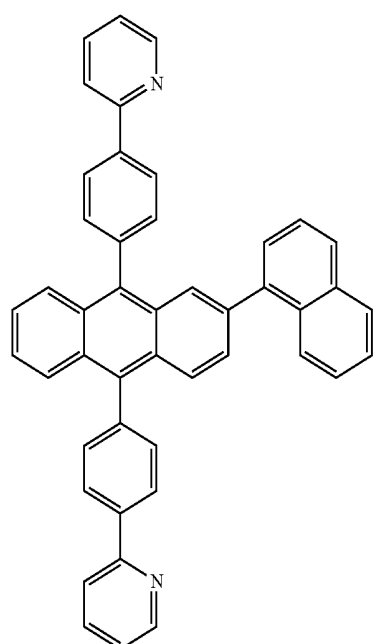
ET11

ET12

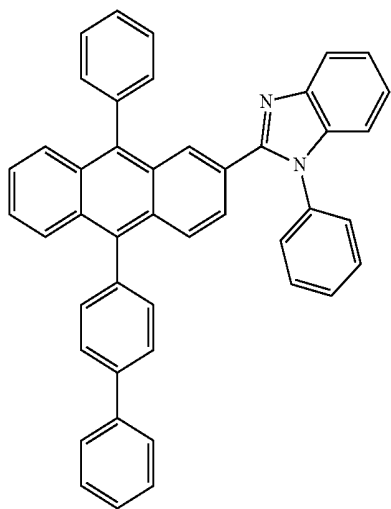


ET10

ET13

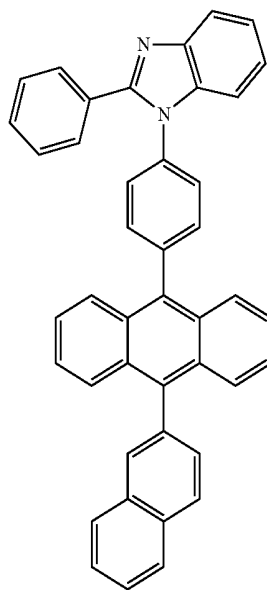


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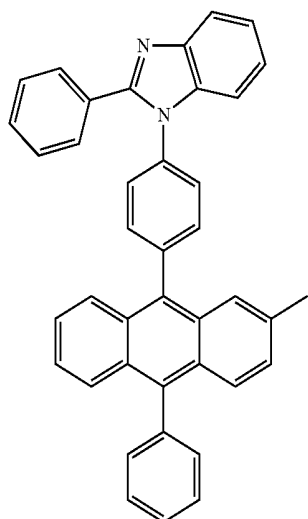
ET14

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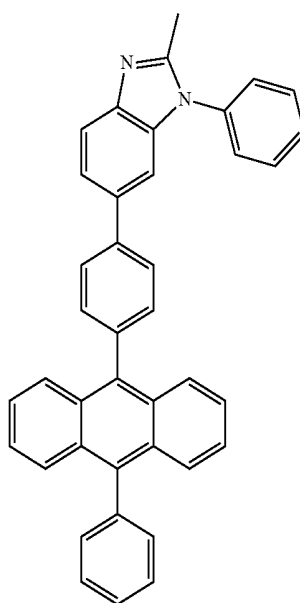


ET17

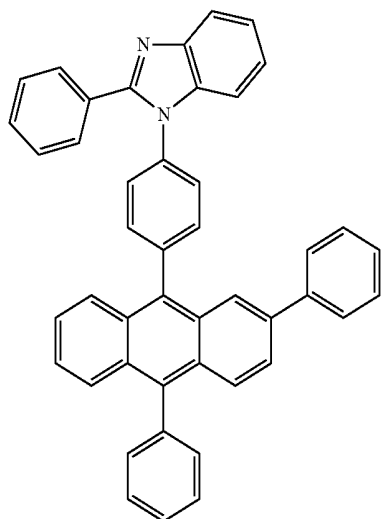
ET15



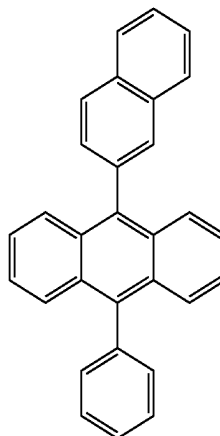
ET18



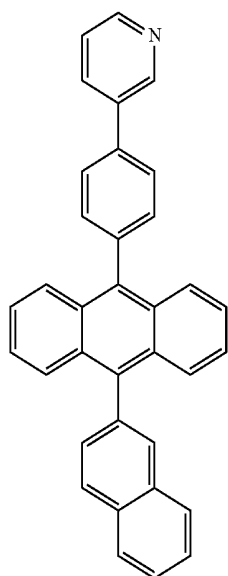
ET16



ET19

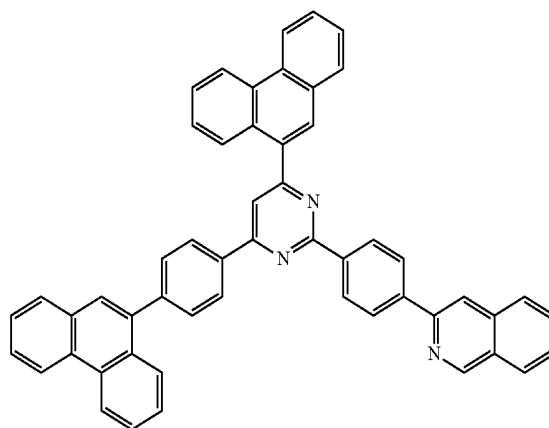


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ET20

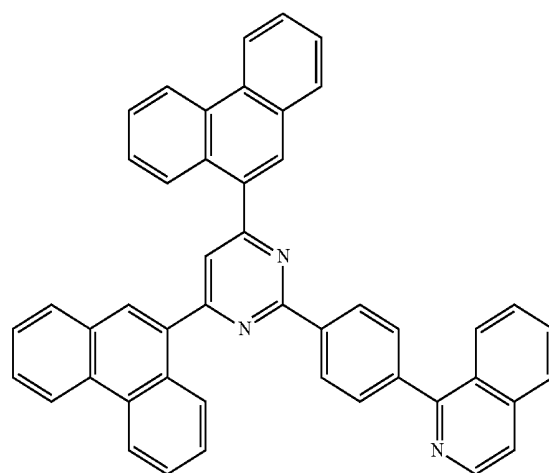
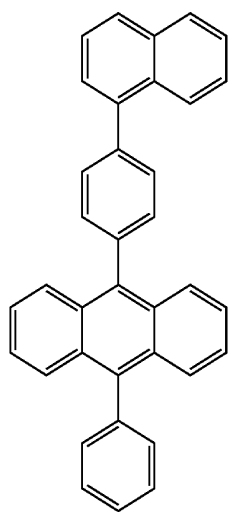
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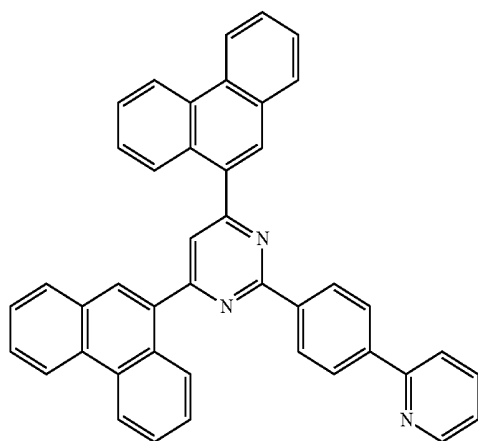
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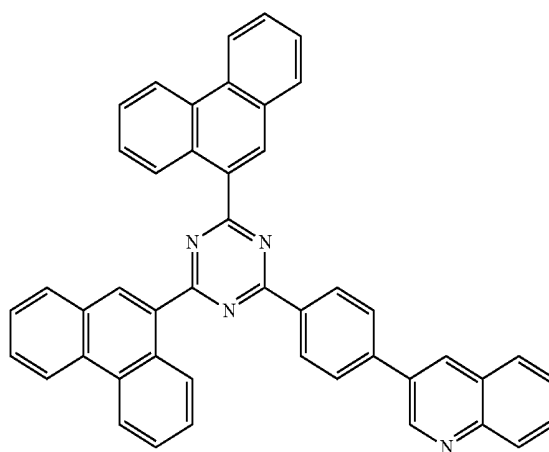
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ET22

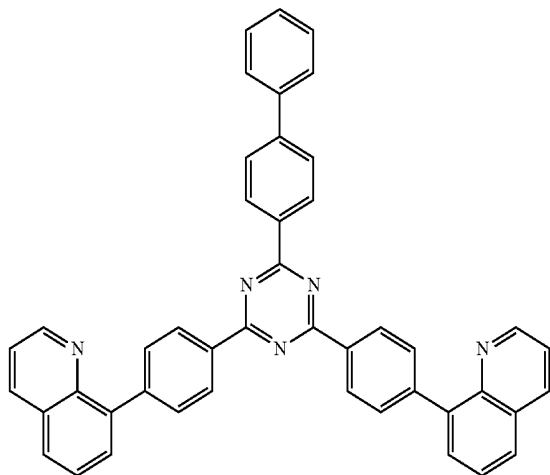


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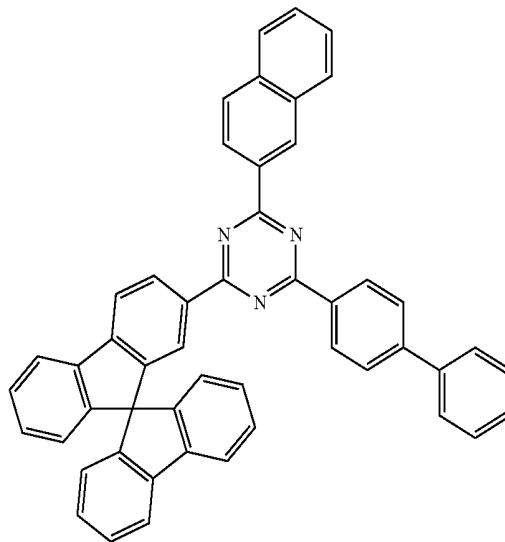
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ET26

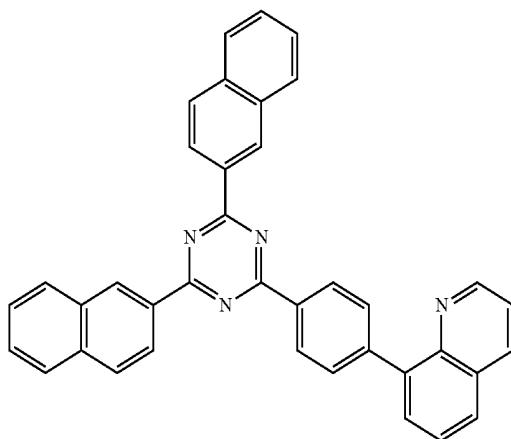


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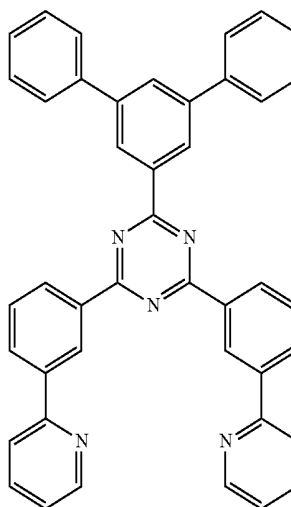
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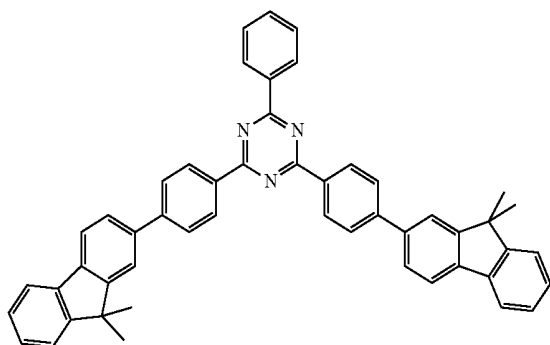
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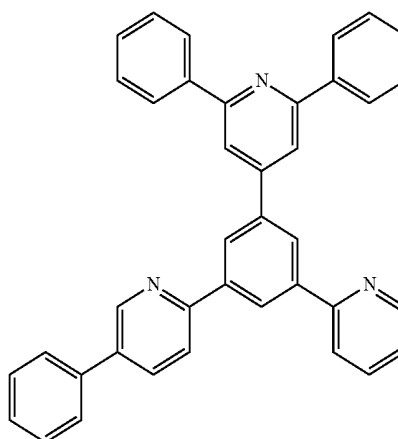
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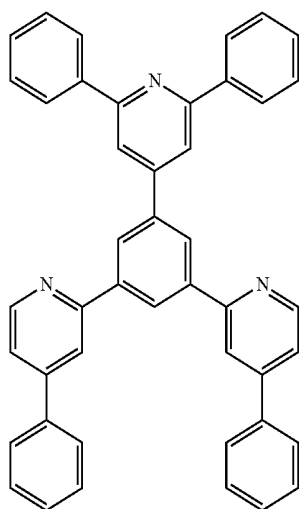
ET28



ET31

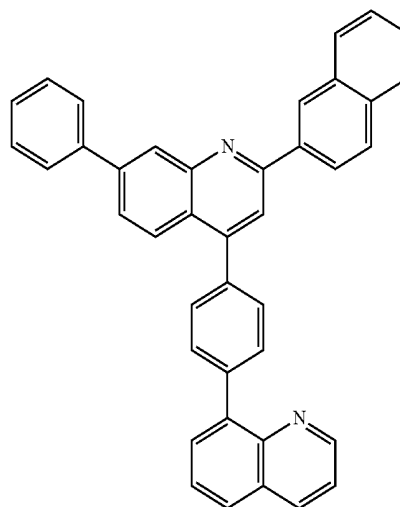


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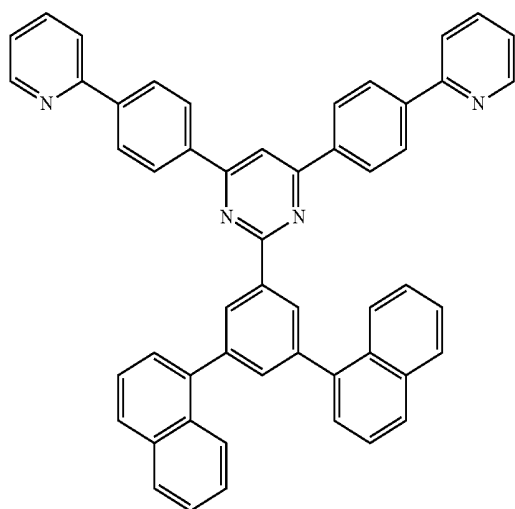
ET32

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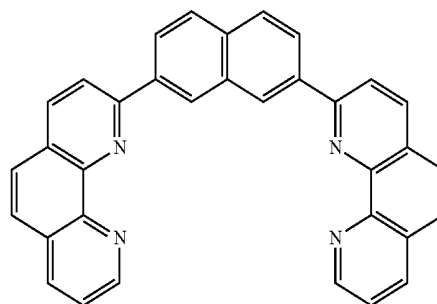


ET35

ET33

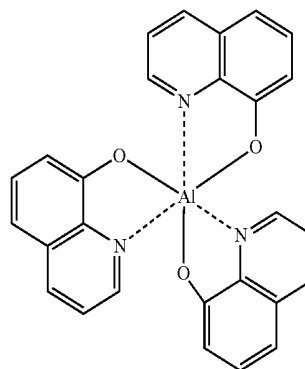
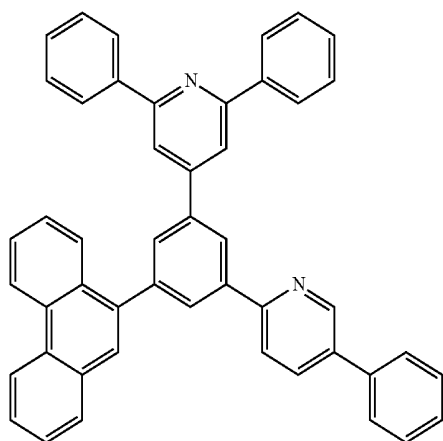


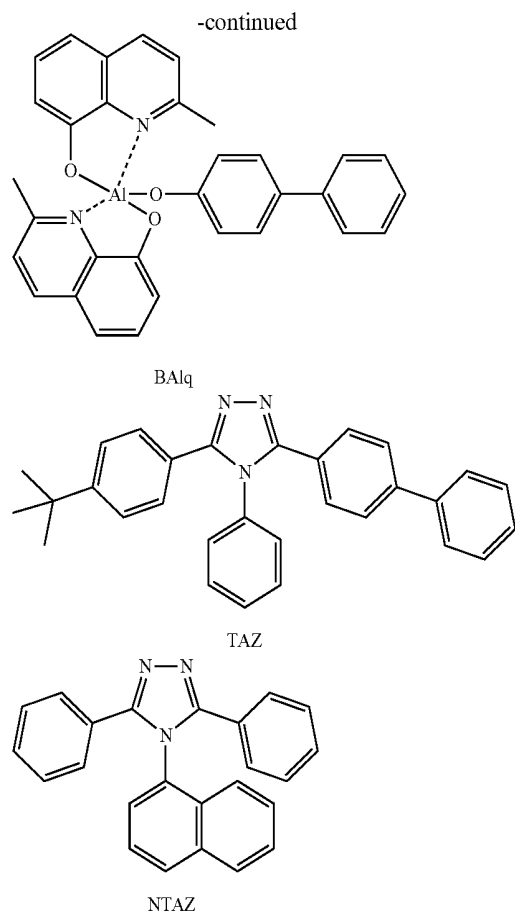
ET36



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

ET34

Alq₃



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

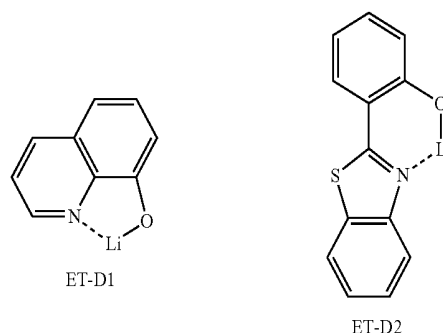
[0329] A thickness of the electron transport layer may be in a range of about 100 Å to about 1,000 Å, for example, about 150 Å to about 500 Å. When the thickness of the electron transport layer is within the range described above, the electron transport layer may have suitable or satisfactory electron transport characteristics without a substantial increase in driving voltage.

[0330] 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.

[0331] The metal-containing material may include at least one selected from alkali metal complex and alkaline earth-metal complex. The alkali metal complex may include a metal ion selected from a Li ion, a Na ion, a K ion, a Rb ion, and a Cs ion, and the alkaline earth-metal complex may include a metal ion selected from a Be ion, a Mg ion, a Ca ion, a Sr ion, and a Ba ion. A ligand coordinated with the metal ion of the alkali metal complex or the alkaline earth-metal complex may be selected from a hydroxy quinoline, a hydroxy isoquinoline, a hydroxy benzoquinoline, a hydroxy acridine, a hydroxy phenanthridine, a hydroxy

phenylan oxazole, a hydroxy phenylthiazole, a hydroxy diphenylan oxadiazole, a hydroxy diphenylthiadiazole, a hydroxy phenylpyridine, a hydroxy phenylbenzimidazole, a hydroxy phenylbenzothiazole, a bipyridine, a phenanthroline, and a cyclopentadiene, but embodiments of the present disclosure are not limited thereto.

[0332] 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.



[0333] The electron transport region may include an electron injection layer that facilitates the injection of electrons from the second electrode **190**. The electron injection layer may directly contact the second electrode **190**.

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

[0335] The electron injection layer may include an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare earth metal complex, or any combinations thereof.

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

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

[0338] The rare earth metal may be selected from Sc, Y, Ce, Tb, Yb, and Gd.

[0339] 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.

[0340] The alkali metal compound may be selected from alkali metal oxides, such as Li₂O, Cs₂O, or K₂O, and alkali metal halides, such as LiF, NaF, CsF, KF, LiI, NaI, CsI, KI, or RbI. In one embodiment, the alkali metal compound may be selected from LiF, Li₂O, NaF, LiI, NaI, CsI, and KI, but embodiments of the present disclosure are not limited thereto.

[0341] The alkaline earth-metal compound may be selected from alkaline earth-metal oxides, such as BaO, SrO,

CaO, $\text{Ba}_x\text{Sr}_{1-x}\text{P}$ ($0 < x < 1$), $\text{Ba}_x\text{Ca}_{1-x}\text{O}$ ($0 < x < 1$). In one embodiment, the alkaline earth-metal compound may be selected from BaO, SrO, and CaO, but embodiments of the present disclosure are not limited thereto.

[0342] 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 embodiment, the rare earth metal compound may be selected from YbF_3 , ScF_3 , TbF_3 , YbI_3 , ScI_3 , and TbI_3 , but embodiments of the present disclosure are not limited thereto.

[0343] The alkali metal complex, the alkaline earth-metal complex, and the rare earth metal complex may include an ion of alkali metal, alkaline earth-metal, and rare earth metal as described above, and a ligand coordinated with a metal ion of the alkali metal complex, the alkaline earth-metal complex, or the rare earth metal complex may be selected from hydroxy quinoline, hydroxy isoquinoline, hydroxy benzoquinoline, hydroxy acridine, hydroxy phenanthridine, hydroxy phenyl an oxazole, hydroxy phenylthiazole, hydroxy diphenyl an oxadiazole, hydroxy diphenylthiadiazole, hydroxy phenylpyridine, hydroxy phenylbenzimidazole, hydroxy phenylbenzothiazole, bipyridine, phenanthroline, and cyclopentadiene, but embodiments of the present disclosure are not limited thereto.

[0344] The electron injection layer may consist of an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare earth metal complex, or any 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.

[0345] A thickness of the electron injection layer may be in a range of about 1 Å to about 100 Å, for example, about 3 Å to about 90 Å. When the thickness of the electron injection layer is within the range described above, the electron injection layer may have suitable or satisfactory electron injection characteristics without a substantial increase in driving voltage.

[0346] The second electrode 190 may be disposed on the organic layer 150 having such a structure. The second electrode 190 may be a cathode which is an electron injection electrode, and in this regard, a material for forming the second electrode 190 may be selected from metal, an alloy, an electrically conductive compound, and a combination thereof, which have a relatively low work function.

[0347] 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.

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

[0349] Hereinbefore, the organic light-emitting device has been described with reference to the accompanying drawing, but embodiments of the present disclosure are not limited thereto.

[0350] Layers constituting the hole transport region, an emission layer, and layers constituting the electron transport region may be formed in a certain region by using one or more suitable methods selected from vacuum deposition, spin coating, casting, Langmuir-Blodgett (LB) deposition, ink-jet printing, laser-printing, and laser-induced thermal imaging.

[0351] When layers constituting the hole transport region, an emission layer, and layers constituting the electron transport region are formed by vacuum deposition, for example, the vacuum deposition may be performed at a deposition temperature of about 100° C. to about 500° C., at a vacuum degree of about 10^{-8} torr to about 10^{-3} torr, and at a deposition rate of about 0.01 Å/sec to about 100 Å/sec by taking into account a material to be included in a layer to be formed, and the structure of a layer to be formed.

[0352] When layers constituting the hole transport region, an emission layer, and layers constituting the electron transport region are formed by spin coating, the spin coating may be performed at a coating speed of about 2,000 rpm to about 5,000 rpm and at a heat treatment temperature of about 80° C. to about 200° C. by taking into account a material to be included in a layer to be formed, and the structure of a layer to be formed.

[0353] The term “ $\text{C}_1\text{-C}_{60}$ alkyl group,” as used herein, refers to a linear or branched saturated aliphatic hydrocarbon monovalent group having 1 to 60 carbon atoms, and non-limiting examples thereof include a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, a pentyl group, an iso-amyl group, and a hexyl group. The term “ $\text{C}_1\text{-C}_{60}$ alkylene group,” as used herein, refers to a divalent group having substantially the same structure as the $\text{C}_1\text{-C}_{60}$ alkyl group, except that the $\text{C}_1\text{-C}_{60}$ alkylene group is divalent instead of monovalent.

[0354] The term “ $\text{C}_2\text{-C}_{60}$ alkenyl group,” as used herein, refers to a hydrocarbon group formed by substituting at least one carbon-carbon double bond at a main chain (e.g., in the middle) or at the terminus of the $\text{C}_2\text{-C}_{60}$ alkyl group, and non-limiting examples thereof include an ethenyl group, a propenyl group, and a butenyl group. The term “ $\text{C}_2\text{-C}_{60}$ alkenylene group,” as used herein, refers to a divalent group having substantially the same structure as the $\text{C}_2\text{-C}_{60}$ alkenyl group, except that the $\text{C}_2\text{-C}_{60}$ alkenylene group is divalent instead of monovalent.

[0355] The term “ $\text{C}_2\text{-C}_{60}$ alkynyl group,” as used herein, refers to a hydrocarbon group having at least one carbon-carbon triple bond at a main chain (e.g., in the middle) or at the terminus of the $\text{C}_2\text{-C}_{60}$ alkyl group, and non-limiting examples thereof include an ethynyl group, and a propynyl group. The term “ $\text{C}_2\text{-C}_{60}$ alkynylene group,” as used herein, refers to a divalent group having substantially the same structure as the $\text{C}_2\text{-C}_{60}$ alkynyl group, except that the $\text{C}_2\text{-C}_{60}$ alkynylene group is divalent instead of monovalent.

[0356] The term “ $\text{C}_1\text{-C}_{60}$ alkoxy group,” as used herein, refers to a monovalent group represented by —OA_{101}

(wherein A_{101} is the C_1 - C_{60} alkyl group), and non-limiting examples thereof include a methoxy group, an ethoxy group, and an isopropoxy group.

[0357] The term " C_3 - C_{10} cycloalkyl group," as used herein, refers to a monovalent saturated hydrocarbon monocyclic group having 3 to 10 carbon atoms, and non-limiting examples thereof include a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. The term " C_3 - C_{10} cycloalkylene group," as used herein, refers to a divalent group having substantially the same structure as the C_3 - C_{10} cycloalkyl group, except that the C_3 - C_{10} cycloalkylene group is divalent instead of monovalent.

[0358] The term " C_1 - C_{10} heterocycloalkyl group," as used herein, refers to a monovalent monocyclic group having at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom and 1 to 10 carbon atoms, and non-limiting examples thereof include a 1,2,3,4-oxatriazolidinyl group, a tetrahydrofuranlyl group, and a tetrahydrothiophenyl group. The term " C_1 - C_{10} heterocycloalkylene group," as used herein, refers to a divalent group having substantially the same structure as the C_1 - C_{10} heterocycloalkyl group, except that the C_1 - C_{10} heterocycloalkylene group is divalent instead of monovalent.

[0359] The term " C_3 - C_{10} cycloalkenyl group," as used herein, refers to a monovalent monocyclic group that has 3 to 10 carbon atoms and at least one carbon-carbon double bond in the ring thereof and no aromaticity (e.g., the ring or the entire group is not aromatic), and non-limiting examples thereof include a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. The term " C_3 - C_{10} cycloalkenylene group," as used herein, refers to a divalent group having substantially the same structure as the C_3 - C_{10} cycloalkenyl group, except that the C_3 - C_{10} cycloalkenylene group is divalent instead of monovalent.

[0360] The term " C_1 - C_{10} heterocycloalkenyl group," as used herein, refers to a monovalent monocyclic group that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, 1 to 10 carbon atoms, and at least one carbon-carbon double bond in its ring. Non-limiting examples of the C_1 - C_{10} heterocycloalkenyl group include a 4,5-dihydro-1,2,3,4-oxatriazolyl group, a 2,3-dihydrofuranlyl group, and a 2,3-dihydrothiophenyl group. The term " C_1 - C_{10} heterocycloalkenylene group," as used herein, refers to a divalent group having substantially the same structure as the C_1 - C_{10} heterocycloalkenyl group, except that the C_1 - C_{10} heterocycloalkenylene group is divalent instead of monovalent.

[0361] The term " C_6 - C_{60} aryl group," as used herein, refers to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms, and the term " C_6 - C_{60} arylene group," as used herein, refers to a divalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms. Non-limiting examples of the C_6 - C_{60} aryl group include a phenyl group, a naphthyl group, an anthracenyl group, a phenanthrenyl group, a pyrenyl group, and a chrysenyl group. When the C_6 - C_{60} aryl group and the C_6 - C_{60} arylene group each include two or more rings, the rings may be fused to each other.

[0362] The term " C_1 - C_{60} heteroaryl group," as used herein, refers to a monovalent group having a heterocyclic aromatic system that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, in addition to 1 to 60 carbon atoms. The term " C_1 - C_{60} heteroarylene

group," as used herein, refers to a divalent group having a heterocyclic aromatic system that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, in addition to 1 to 60 carbon atoms. Non-limiting examples of the C_1 - C_{60} heteroaryl group include a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, and an isoquinolinyl group. When the C_1 - C_{60} heteroaryl group and the C_1 - C_{60} heteroarylene group each include two or more rings, the rings may be fused to each other (e.g., the rings may be combined together).

[0363] The term " C_6 - C_{60} aryloxy group," as used herein, indicates $-OA_{102}$ (wherein A_{102} is the C_6 - C_{60} aryl group), and the term " C_6 - C_{60} arylthio group," as used herein, indicates $-SA_{103}$ (wherein A_{103} is the C_6 - C_{60} aryl group).

[0364] The term "monovalent non-aromatic condensed polycyclic group," as used herein, refers to a monovalent group (for example, having 8 to 60 carbon atoms) having two or more rings condensed with each other (e.g., two or more rings combined or fused together), only carbon atoms as ring-forming atoms, and no aromaticity in its entire molecular structure (e.g., the entire molecular structure is non-aromatic). A detailed, non-limiting, example of the monovalent non-aromatic condensed polycyclic group is a fluorenyl group. The term "divalent non-aromatic condensed polycyclic group," as used herein, refers to a divalent group having substantially the same structure as the monovalent non-aromatic condensed polycyclic group, except that the divalent non-aromatic condensed polycyclic group is divalent instead of monovalent.

[0365] The term "monovalent non-aromatic condensed heteropolycyclic group," as used herein, refers to a monovalent group (for example, having 1 to 60 carbon atoms) having two or more rings condensed to each other (e.g., two or more rings combined or fused together), at least one heteroatom selected from N, O, Si, P, and S, other than carbon atoms, as a ring-forming atom, and no aromaticity in its entire molecular structure (e.g., the entire molecular structure is non-aromatic). A non-limiting example of the monovalent non-aromatic condensed heteropolycyclic group is a carbazolyl group. The term "divalent non-aromatic condensed heteropolycyclic group," as used herein, refers to a divalent group having substantially the same structure as the monovalent non-aromatic condensed heteropolycyclic group, except that the divalent non-aromatic condensed heteropolycyclic group is divalent instead of monovalent.

[0366] The term " C_5 - C_{60} carbocyclic group," as used herein, refers to a monocyclic or polycyclic group having 5 to 60 carbon atoms in which a ring-forming atom is a carbon atom only. The C_5 - C_{60} carbocyclic group may be an aromatic carbocyclic group or a non-aromatic carbocyclic group. The C_5 - C_{60} carbocyclic group may be a ring, such as a benzene group, 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.

[0367] The term " C_1 - C_{60} heterocyclic group," as used herein, refers to a group having the same structure as the C_1 - C_{60} carbocyclic group, except that as a ring-forming atom, at least one heteroatom selected from N, O, Si, P, and

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

[0368] At least one substituent of the substituted C₅-C₆₀ carbocyclic group, the substituted C₁-C₆₀ heterocyclic group, the substituted C₃-C₁₀ cycloalkylene group, the substituted C₁-C₁₀ heterocycloalkylene group, the substituted C₃-C₁₀ cycloalkenylene group, the substituted C₁-C₁₀ heterocycloalkenylene group, the substituted C₆-C₆₀ arylene group, the substituted C₁-C₆₀ heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, the substituted divalent non-aromatic condensed heteropolycyclic group, the substituted C₁-C₆₀ alkyl group, the substituted C₂-C₆₀ alkenyl group, the substituted C₂-C₆₀ alkynyl group, the substituted C₁-C₆₀ alkoxy group, the substituted C₃-C₁₀ cycloalkyl group, the substituted C₁-C₁₀ heterocycloalkyl group, the substituted C₃-C₁₀ cycloalkenyl group, the substituted C₁-C₁₀ heterocycloalkenyl group, the substituted C₆-C₆₀ aryl group, the substituted C₆-C₆₀ aryloxy group, the substituted C₆-C₆₀ arylthio group, the substituted C₁-C₆₀ heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from:

[0369] deuterium (-D), -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group;

[0370] a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, -Si(Q₁₁)(Q₁₂)(Q₁₃), -N(Q₁₁)(Q₁₂), -B(Q₁₁)(Q₁₂), -C(=O)(Q₁₁), -S(=O)₂(Q₁₁), and -P(=O)(Q₁₁)(Q₁₂);

[0371] a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

[0372] a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, -Si(Q₂₁)(Q₂₂)(Q₂₃), -N(Q₂₁)(Q₂₂), -B(Q₂₁)(Q₂₂), -C(=O)(Q₂₁), -S(=O)₂(Q₂₁), and -P(=O)(Q₂₁)(Q₂₂); and

[0373] -Si(Q₃₁)(Q₃₂)(Q₃₃), -N(Q₃₁)(Q₃₂), -B(Q₃₁)(Q₃₂), -C(=O)(Q₃₁), -S(=O)₂(Q₃₁), and -P(=O)(Q₃₁)(Q₃₂),

[0374] wherein Q₁₁ to Q₁₃, Q₂₁ to Q₂₃, and Q₃₁ to Q₃₃ may each independently be selected from hydrogen, deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

[0375] 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.

[0376] The term “biphenyl group,” as used herein, refers to “a phenyl group substituted with a phenyl group.” In other words, the “biphenyl group” is a substituted phenyl group having a C₆-C₆₀ aryl group as a substituent.

[0377] The “terphenyl group,” as used herein, refers to “a phenyl group substituted with a biphenyl group.” In other words, the “terphenyl group” is a phenyl group having, as a substituent, a C₆-C₆₀ aryl group substituted with a C₆-C₆₀ aryl group.

[0378] * and *, as used herein, unless defined otherwise, each refer to a binding site to a neighboring atom in a corresponding formula.

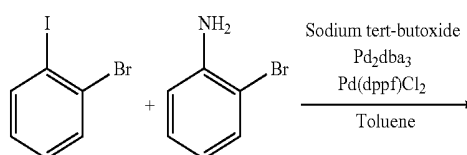
[0379] Hereinafter, a compound according to embodiments and an organic light-emitting device according to embodiments will be described in more detail with reference to Synthesis Examples and Examples. The expression “B was used instead of A” used in describing Synthesis Examples and Examples means that an identical or substantially identical number of molar equivalents of A was used in place of molar equivalents of B.

SYNTHESIS EXAMPLE

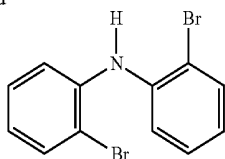
Synthesis of Compound 1

1) Synthesis of bis(2-bromophenylamine)

[0380]



-continued

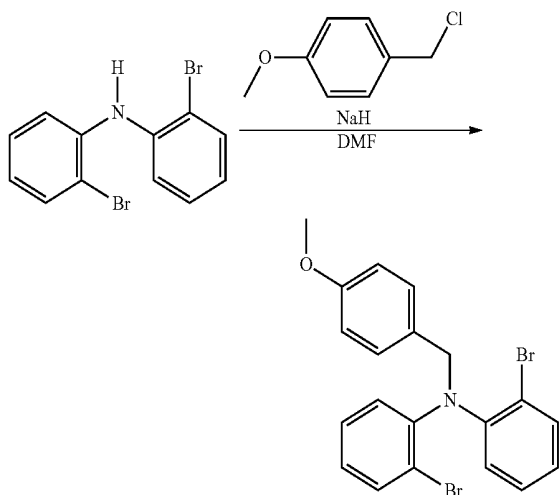


[0381] 15 g (0.087 mol) of 2-bromoaniline and 29.6 g (0.105 mol) of 1-bromo-2-iodobenzene were dissolved in 200 mL of toluene in a 500-mL three-neck round bottom flask, and 16.76 g (0.174 mol) of sodium tert-butoxide, 12.76 g (0.017 mol) of Pd(dppf)Cl_2 , and 7.98 g (0.009 mol) of Pd_2dba_3 were added thereto. The mixture was stirred under reflux for 12 hours. When the reaction was substantially completed, the solvent was removed from the mixture, and an extraction process was performed thereon three times by using methylene chloride (MC). An extracted organic layer was dried by using MgSO_4 and the solvent was removed therefrom by using a rotary evaporator. The residue obtained therefrom was separated using an n-hexane solvent by column chromatography to obtain 18.3 g (yield=64%) of a colorless oil-like compound.

[0382] $^1\text{H-NMR}$ (300 MHz, CDCl_3) [ppm] δ =7.64-7.61 (d, 2H), 7.35-7.32 (d, 2H), 7.28-7.22 (t, 2H), 6.91-6.85 (t, 2H), 6.50 (s, 1H).

2) Synthesis of

N,N-bis(2-bromophenyl)-N-(4-methoxybenzyl)amine

[0383]

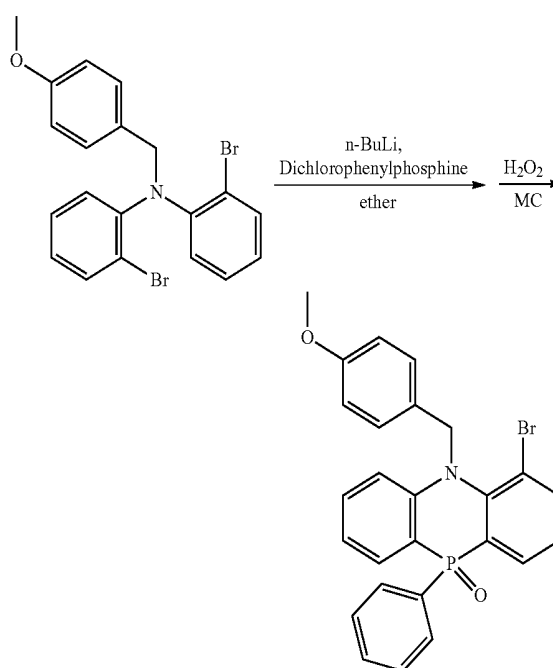
[0384] 39 g (119.2 mmol) of bis(2-bromophenyl)amine, 3.43 g (143.1 mol) of NaH, and 250 mL of dimethylformamide (DMF) were added to a well-dried 500-mL three-neck round bottom flask in an nitrogen atmosphere and stirred at room temperature (25° C.) for 1 hour. Then, 20.54 g (131.2 mol) of 1-(chloromethyl)-4-methoxybenzene was added thereto dropwise and stirred at room temperature for 14 hours. After the reaction was substantially completed, 500 mL of distilled water was added to the reaction mixture dropwise to filter and separate a precipitated solid. The filtered solid was redissolved in MC and an extraction process was performed thereon three times. An extracted organic layer was dried by using MgSO_4 and the solvent was

evaporated by using a rotary evaporator. The residue obtained therefrom was separated using a solvent (MC: hexane=3:1) by column chromatography to obtain 46.8 g (yield=87%) of a compound.

[0385] $^1\text{H-NMR}$ (300 MHz, DMSO) [ppm] δ =7.64-7.61 (d, 2H), 7.5 (d, 2H), 7.3 (t, 2H), 7.0 (m, 4H), 6.80 (d, 2H), 4.7 (s, 2H), 3.7 (s, 3H).

3) Synthesis of

5-(4-methoxybenzyl)-10-phenyl-5H-phenophosphazine 10-oxide

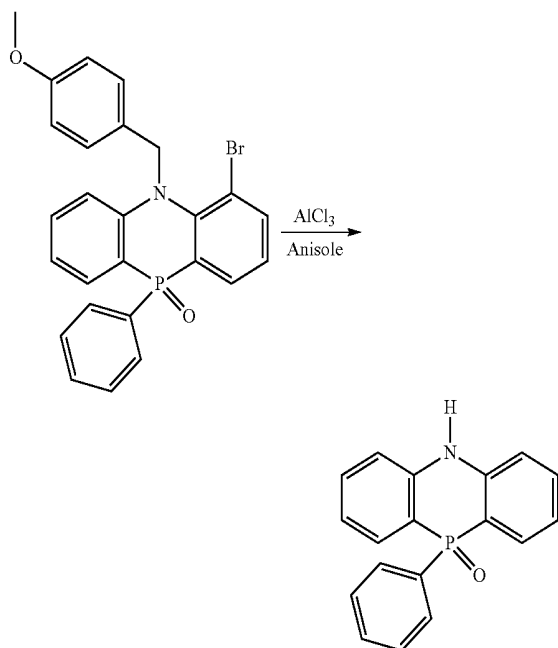
[0386]

[0387] 7.00 g (15.6 mmol) of 2-bromo-N-(2-bromophenyl)-N-(4-methoxybenzyl)aniline and 100 mL of ether were added to a 150-mL three-neck round bottom flask and then stirred. A reaction temperature was lowered to a temperature of -5° C., and 13.8 mL (34.4 mmol) of 2.5M n-BuLi/Hex was added thereto dropwise. After the resultant mixture was stirred for 40 minutes while maintaining the reaction temperature, the reaction temperature was lowered to a temperature of -78° C. and 2.5 mL (18.8 mmol) of dichlorophenylphosphine dissolved in 20 mL of ether was added thereto dropwise. Then, the resultant mixture was stirred at room temperature for 12 hours. After the reaction was substantially completed, the solvent was removed therefrom, and an extraction process was performed thereon three times by using ethyl acetate. An extracted organic layer was dried by using MgSO_4 , and the solvent was removed therefrom by using a rotary evaporator. 70 mL of methylene dichloride and 30 mL of H_2O_2 were added thereto and stirred at room temperature for 12 hours. An extraction process was performed thereon three times by using methylene dichloride. Then, an extracted organic layer was dried by using MgSO_4 , and the solvent was evaporated by using a rotary evaporator. The residue obtained therefrom was separated using a solvent (ethyl acetate:hexane=5:1) by column chromatography to obtain 4 g (yield=52%) of a compound.

[0388] $^1\text{H-NMR}$ (300 MHz, DMSO) [ppm] δ =7.85-7.77 (dd, 2H), 7.65-7.58 (dd, 2H), 7.52-7.42 (m, 5H), 7.19-7.13 (m, 6H), 6.96-6.92 (d, 2H), 5.37 (s, 2H), 3.83 (s, 3H).

4) Synthesis of 10-phenyl-5H-phenophosphazine 10-oxide

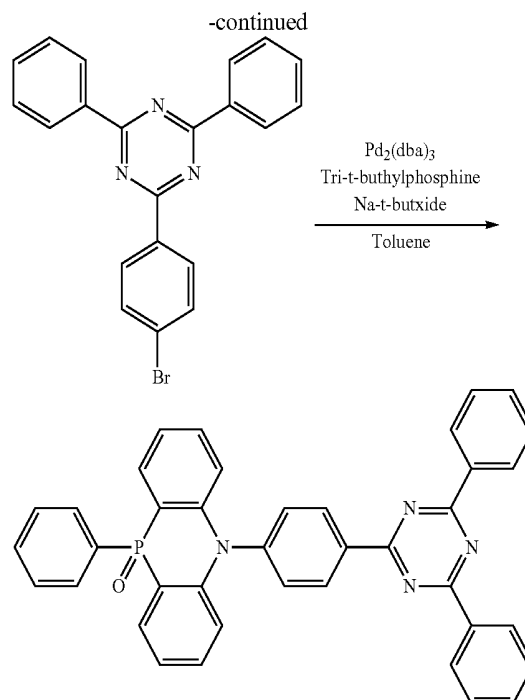
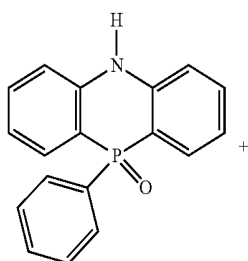
[0389]



[0390] 29.17 g (218.7 mmol) of AlCl_3 and 200 mL of anisole were added to a 100-mL three-neck round bottom flask. A reaction temperature was lowered to -5°C . and 12 g (29.1 mmol) of 5-(4-methoxybenzyl)-10-phenyl-5H-phenophosphazine 10-oxide was dissolved in 100 mL of anisole and stirred at a temperature of 70°C . for 14 hours. After the reaction was substantially completed, H_2O was added thereto and an extraction process was performed thereon three times by using a toluene solvent. An extracted organic layer was dried by using MgSO_4 , and the solvent was removed therefrom by using a rotary evaporator. The residue obtained therefrom was separated using an ethyl acetate/methanol (9:1) solvent by column chromatography to obtain 5.6 g (yield=66%) of a compound.

5) Synthesis of Compound 1

[0391]



[0392] 3.2 g (8.24 mmol) of 2-(4-bromophenyl)-4,6-diphenyl-1,3,5-triazine, 2 g (6.87 mmol) of 10-phenyl-5H-phenophosphazine 10-oxide, 1.98 g (20.60 mmol) of sodium-tert-butoxide, 0.14 g (0.69 mmol) of tris(tert-butyl) phosphine, and 0.31 g (0.34 mmol) of $\text{Pd}_2(\text{dba})_3$ were dissolved in 50 mL of toluene and stirred at a temperature of 110°C . for 12 hours in a 30-mL three-neck round bottom flask. After the reaction was substantially completed, water was added thereto, and an extraction process was performed thereon three times by using chloroform. An extracted organic layer was dried by using MgSO_4 , and the solvent was removed therefrom by using a rotary evaporator. The residue obtained therefrom was separated using an ethyl acetate solvent by column chromatography to obtain 0.54 g (yield=63%) of Compound 1.

[0393] $^1\text{H-NMR}$ (300 MHz, CD_2Cl_2) [ppm] δ =9.18-9.14 (d, 2H), 8.90-8.86 (d, 4H), 7.85-7.64 (m, 12H), 7.54-7.50 (m, 3H), 7.41-7.36 (t, 2H), 7.16-7.11 (t, 2H), 6.71-6.67 (t, 2H). Mass: $\text{C}_{39}\text{H}_{27}\text{N}_4\text{OP}$ calcd. 598.19; found. 598.19.

EXAMPLE

Example 1

[0394] As an anode, a Corning $15\ \Omega/\text{cm}^2$ ($1,000\ \text{\AA}$) ITO glass substrate was cut to a size of $50\ \text{mm} \times 50\ \text{mm} \times 0.5\ \text{mm}$, sonicated with isopropyl alcohol and pure water each for 10 minutes, and then cleaned by exposure to ultraviolet rays and ozone for 10 minutes. Then, the resultant ITO glass substrate was provided to a vacuum deposition apparatus.

[0395] DNTPD was vacuum-deposited on the ITO glass substrate to form a hole injection layer having a thickness of $600\ \text{\AA}$, and NPB was vacuum-deposited on the hole injection layer to form a hole transport layer having a thickness of $600\ \text{\AA}$.

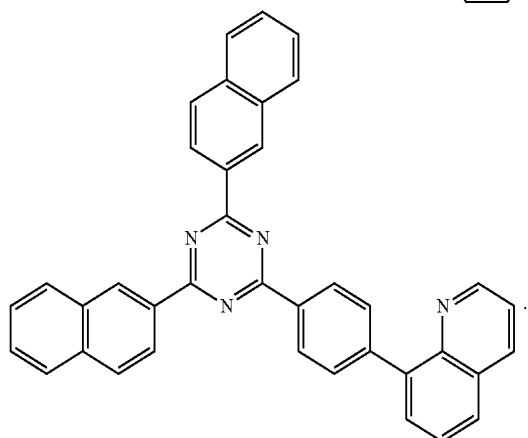
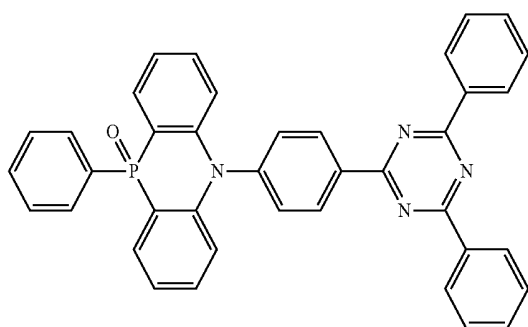
[0396] CBP was vacuum-deposited on the hole transport layer to form a B auxiliary layer having a thickness of $100\ \text{\AA}$, and Flrpic (blue phosphorescent dopant) and Compound

1 (host) were co-deposited on the B auxiliary layer to a weight ratio of 300:15 to form a blue emission layer having a thickness of 300 Å.

[0397] Then, TSPO was vacuum-deposited on the emission layer to form a hole blocking layer having a thickness of 100 Å, and ET1 and LiQ were vacuum-deposited on the hole blocking layer at a ratio of 50:50 to form an electron transport layer having a thickness of 300 Å.

[0398] LiQ was vacuum-deposited on the electron transport layer to form an electron injection layer having a thickness of 20 Å, and Al was vacuum-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.

Compound 1

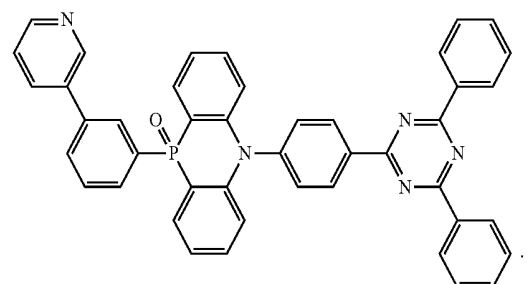


ET 1

Example 2

[0399] 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 in forming an emission layer.

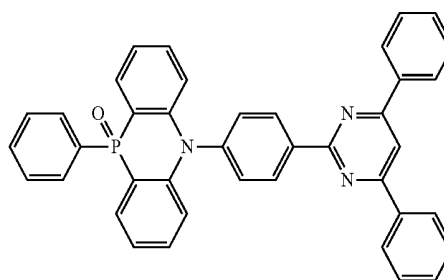
Compound 2



Example 3

[0400] 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 in forming an emission layer.

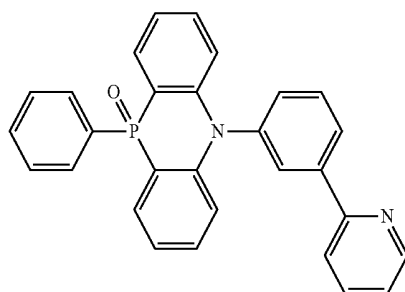
Compound 3



Example 4

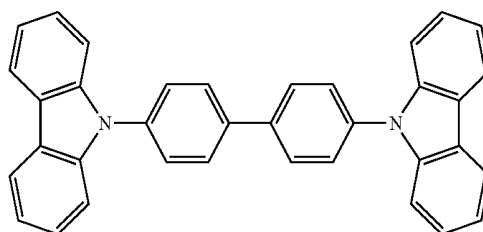
[0401] An organic light-emitting device was manufactured in substantially the same manner as in Example 1, except that Compound 4 was used instead of Compound 1 in forming an emission layer.

Compound 4



Comparative Example 1

[0402] An organic light-emitting device was manufactured in substantially the same manner as in Example 1, except that CBP was used instead of Compound 1 in forming an emission layer.



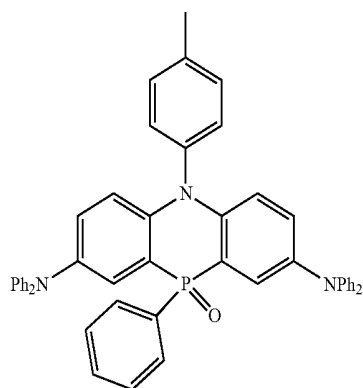
CBP

Comparative Example 2

[0403] An organic light-emitting device was manufactured in substantially the same manner as in Example 1,

except that Comparative Compound 1 was used instead of Compound 1 in forming an emission layer.

Comparative Compound 1



Evaluation Example 1

[0404] A driving voltage, emission efficiency, and color coordinates of the organic light-emitting devices manufactured according to Examples 1 to 4 and Comparative Examples 1 and 2 were measured by using a Keithley SMU 236 and a luminance meter PR650 at 600 nit. Results thereof are shown in Table 1.

TABLE 1

	Driving voltage (V)	Emission efficiency (cd/A)	Color coordinates
Example 1 (Compound 1)	5.1	27.4	(0.18, 0.31)
Example 2 (Compound 2)	5.3	26.8	(0.18, 0.30)
Example 3 (Compound 3)	5.2	25.2	(0.18, 0.32)
Example 4 (Compound 4)	5.9	23.8	(0.17, 0.29)
Comparative Example 1 (CBP)	7.8	18.3	(0.18, 0.30)
Comparative Example 2 (Comparative Compound 1)	4.8	8.2	(0.18, 0.33)

[0405] Referring to Table 1, it is confirmed that the driving voltage of each of the organic light-emitting devices of Examples 1 to 4 is lower than the driving voltage of each of the organic light-emitting devices of Comparative Examples 1 and 2. Also, it is confirmed that the emission efficiency of each of the organic light-emitting devices of Examples 1 to 4 is more excellent than the emission efficiency of the organic light-emitting devices of Comparative Examples 1 and 2.

[0406] According to one or more embodiments, an organic light-emitting device including the heterocyclic compound may have a low driving voltage, high efficiency, high luminance, and a long lifespan.

[0407] 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.

[0408] It will be understood that, although the terms “first,” “second,” “third,” etc., may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms are used to distinguish one element, component, region, layer or section from another element, component, region, layer or section. Thus, a first element, component, region, layer or section described below could be termed a second element, component, region, layer or section, without departing from the spirit and scope of the present disclosure.

[0409] Spatially relative terms, such as “beneath,” “below,” “lower,” “under,” “above,” “upper,” and the like, may be used herein for ease of explanation to describe one element or feature’s relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or in operation, in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as “below” or “beneath” or “under” other elements or features would then be oriented “above” the other elements or features. Thus, the example terms “below” and “under” can encompass both an orientation of above and below. The device may be otherwise oriented (e.g., rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein should be interpreted accordingly.

[0410] It will be understood that when an element or layer is referred to as being “on,” “connected to,” or “coupled to” another element or layer, it can be directly on, connected to, or coupled to the other element or layer, or one or more intervening elements or layers may be present. In addition, it will also be understood that when an element or layer is referred to as being “between” two elements or layers, it can be the only element or layer between the two elements or layers, or one or more intervening elements or layers may also be present.

[0411] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the present disclosure. As used herein, the singular forms “a” and “an” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises,” “comprising,” “includes,” and “including,” when used in this specification, specify the presence of the stated features, integers, acts, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, acts, operations, elements, components, and/or groups thereof.

[0412] 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. Further, the use of “may” when describing embodiments of the present disclosure refers to “one or more embodiments of the present disclosure.” As used herein, the terms “use,” “using,” and “used” may be considered synonymous with

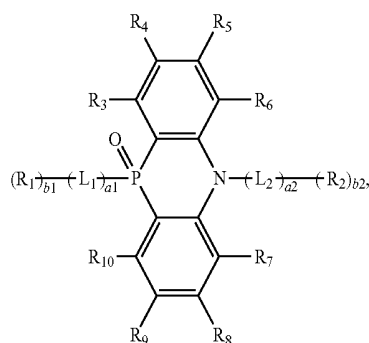
the terms “utilize,” “utilizing,” and “utilized,” respectively. Also, the term “exemplary” is intended to refer to an example or illustration.

[0413] Also, any numerical range recited herein is intended to include all subranges 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.

[0414] While one or more embodiments have been described with reference to the accompanying drawing, 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 heterocyclic compound represented by Formula 1:



Formula 1

wherein, in Formula 1,

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,

R_1 and R_3 to R_{10} are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, —Si(Q_{31})(Q_{32})(Q_{33}), P(=O)(Q_{31})(Q_{32}), 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, a biphenyl group, and a terphenyl group, R_2 is (i) a C_6 - C_{60} aryl group substituted with at least one electron withdrawing group or (ii) a substituted or unsubstituted π electron-depleted nitrogen-containing ring group,

a_1 is an integer from 0 to 5,

a_2 is an integer from 0 to 5,

b_1 is an integer from 0 to 5,

b_2 is an integer from 1 to 5,

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, the substituted monovalent non-aromatic condensed heteropolycyclic group, and the substituted π electron-depleted nitrogen-containing ring 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_1 - C_{10} heterocycloalkenyl 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_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group;

a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60}

alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group; and
 $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, $-\text{N}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{B}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{C}(=\text{O})(\text{Q}_{31})$, $-\text{S}(=\text{O})_2(\text{Q}_{31})$, and $-\text{P}(=\text{O})(\text{Q}_{31})(\text{Q}_{32})$, and

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

2. The heterocyclic compound of claim 1, wherein:

R₁ and R₃ to R₁₀ are each independently selected from: hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-fluorene-benzofluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a biphenyl group, and a terphenyl group; and

a phenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-fluorene-benzofluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a

hydrazino group, a hydrazono group, $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-fluorene-benzofluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a biphenyl group, and a terphenyl group, and

Q₃₁ to Q₃₃ are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryl group substituted with a C₁-C₆₀ alkyl group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

3. The heterocyclic compound of claim 1, wherein:

R₁ is selected from:

hydrogen, deuterium, a phenyl group, a naphthyl group, a fluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a biphenyl group, and a terphenyl group; and

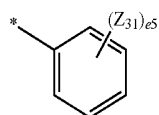
a phenyl group, a naphthyl group, a fluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a

cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a biphenyl group, and a terphenyl group, and

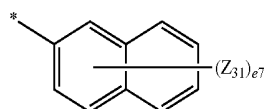
Q_{31} to Q_{33} are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{60} alkyl group, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryl group substituted with a C_r , C_{60} alkyl group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

4. The heterocyclic compound of claim 1, wherein:

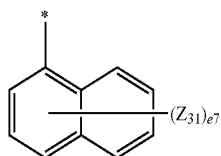
R_1 is selected from groups represented by Formulae A-1 to A-15:



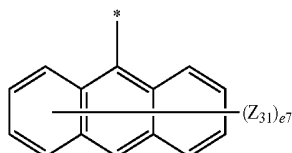
A-1



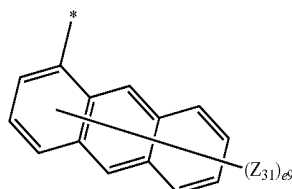
A-2



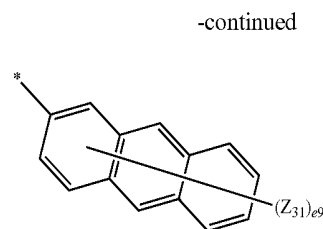
A-3



A-4

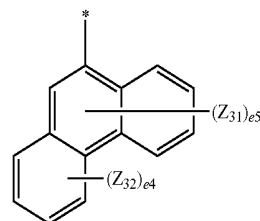


A-5

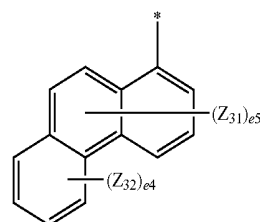


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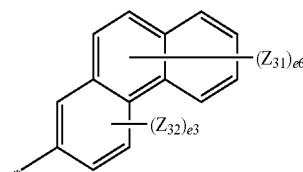
A-6



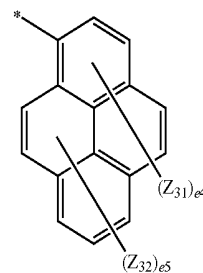
A-7



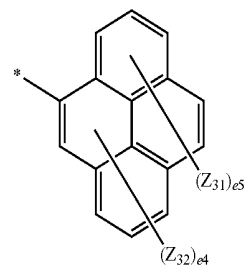
A-8



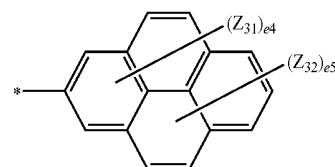
A-9



A-10

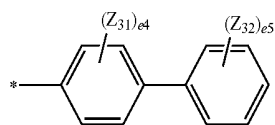


A-11

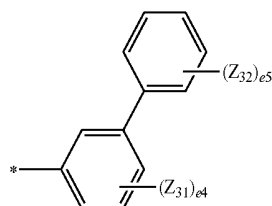


A-12

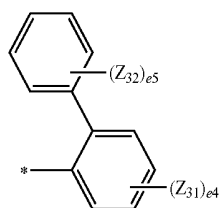
-continued



A-13



A-14



A-15

wherein, in Formulae A-1 to A-15,

Z_{31} and Z_{32} are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkenyl group, a C_1 - C_{20} alkynyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, —Si(Q_{31})(Q_{32})(Q_{33}), —N(Q_{31})(Q_{32}), —B(Q_{31})(Q_{32}), —C(=O)(Q_{31}), —S(=O)₂(Q_{31}), and —P(=O)(Q_{31})(Q_{32}),

Q_{31} to Q_{33} are each independently selected from a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a phenyl group substituted with a C_1 - C_{10} alkyl group, a biphenyl group, a terphenyl group, a naphthyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothioiophenyl group,

e3 is an integer from 1 to 3,

e4 is an integer from 1 to 4,

e5 is an integer from 1 to 5,

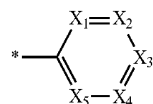
e6 is an integer from 1 to 6,

e7 is an integer from 1 to 7,

e9 is an integer from 1 to 9, and

* indicates a binding site to a neighboring atom.

5. The heterocyclic compound of claim 1, wherein:
 R_2 is represented by Formula 2:



Formula 2

wherein, in Formula 2,

X_1 is N or CAr_1 ,

X_2 is N or CAr_2 ,

X_3 is N or CAr_3 ,

X_4 is N or CAr_4 , and

X_5 is N or CAr_5 ,

Ar_1 to Ar_5 are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, —Si(Q_{31})(Q_{32})(Q_{33}), P(=O)(Q_{31})(Q_{32}), 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 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, and Ar_1 to Ar_5 are optionally linked to form a substituted or unsubstituted ring,

provided that (i) at least one of X_1 to X_5 is N, or (ii) at least one of Ar_1 to Ar_5 is a substituted or unsubstituted π electron-depleted nitrogen-containing ring group or an electron withdrawing group,

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, the substituted monovalent non-aromatic condensed heteropolycyclic group, and the substituted π electron-depleted nitrogen-containing ring 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 sub-

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

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

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

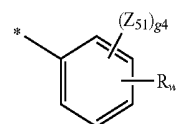
—Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂).

Q₃₁ to Q₃₃ are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryl group substituted with a C₁-C₆₀ alkyl group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, and

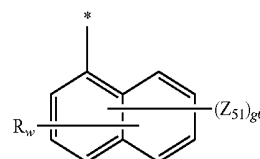
* indicates a binding site to a neighboring atom.

6. The heterocyclic compound of claim 1, wherein:

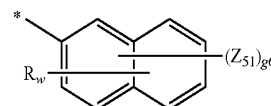
R₂ is selected from groups represented by Formulae W-1 to W-16 and N-1 to N-59:



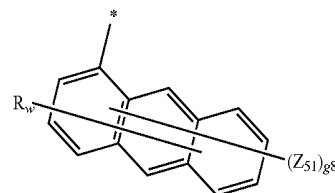
W-1



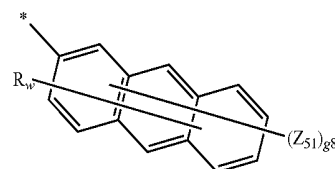
W-2



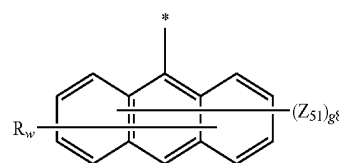
W-3



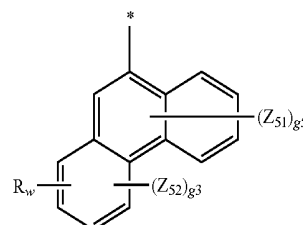
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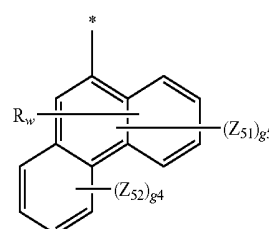
W-5



W-6

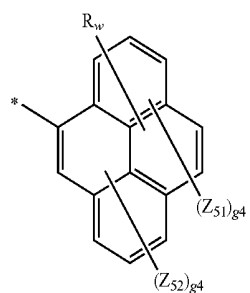
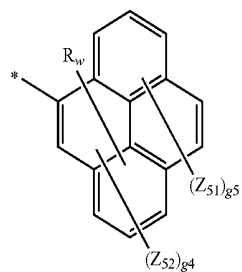
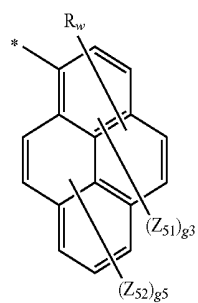
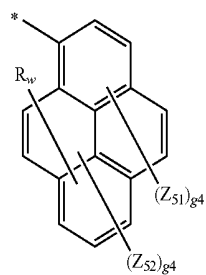
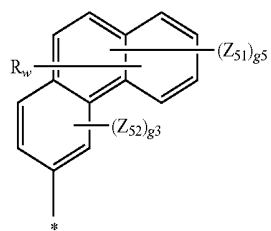
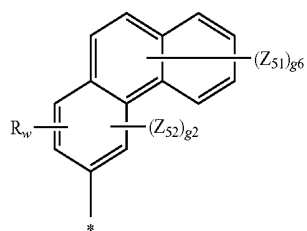


W-7



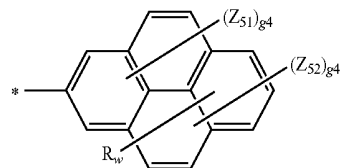
W-8

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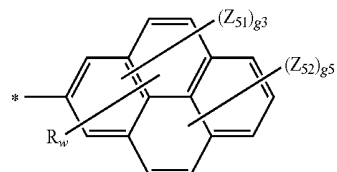
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W-9



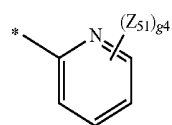
W-15

W-10

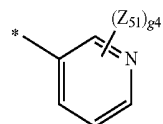


W-16

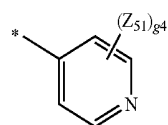
W-11



N-1

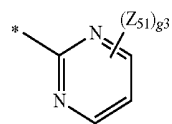


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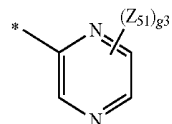


N-3

W-12

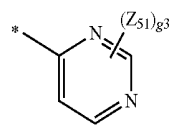


N-4

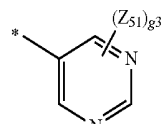


N-5

W-13

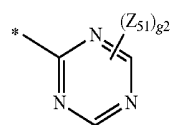


N-6

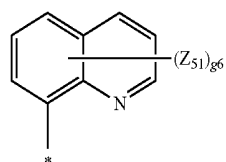


N-7

W-14



N-8

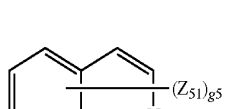
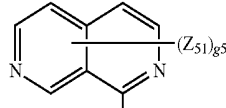
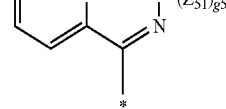
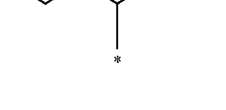
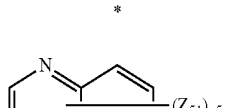
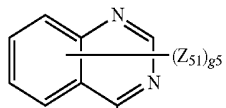
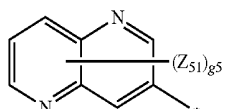
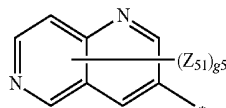
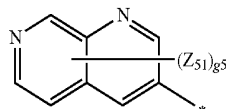
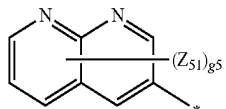
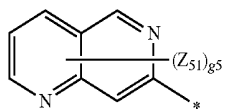


N-9

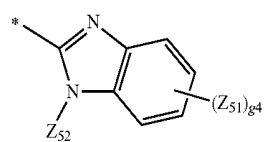
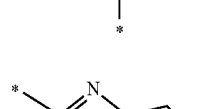
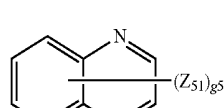
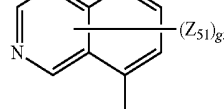
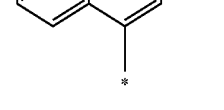
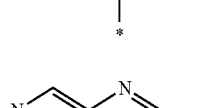
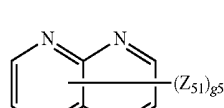
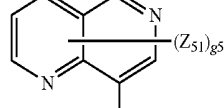
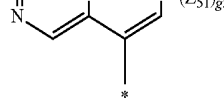
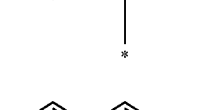
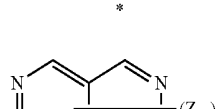
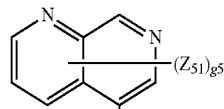
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N-42

N-43

N-44

N-45

N-46

N-47

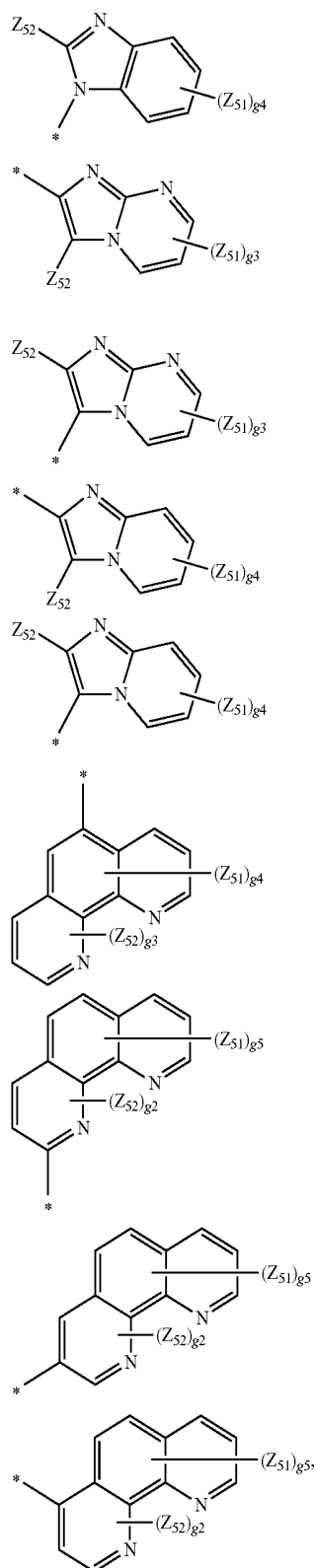
N-48

N-49

N-50

-continued

N-51



wherein, in Formulae W-1 to W-16,

R_w is selected from a cyano group, a C_1 - C_{20} fluoroalkyl group, and groups represented by Formulae N-1 to N-59, and

in Formulae W-1 to W-16 and N-1 to N-59, Z_{51} and Z_{52} are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} fluoroalkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, an imidazolyl group, a pyrazole group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a triazinyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl 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 oxadiazolyl group, a thiadiazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group,

g_2 is an integer from 0 to 2,

g_3 is an integer from 0 to 3,

g_4 is an integer from 0 to 4,

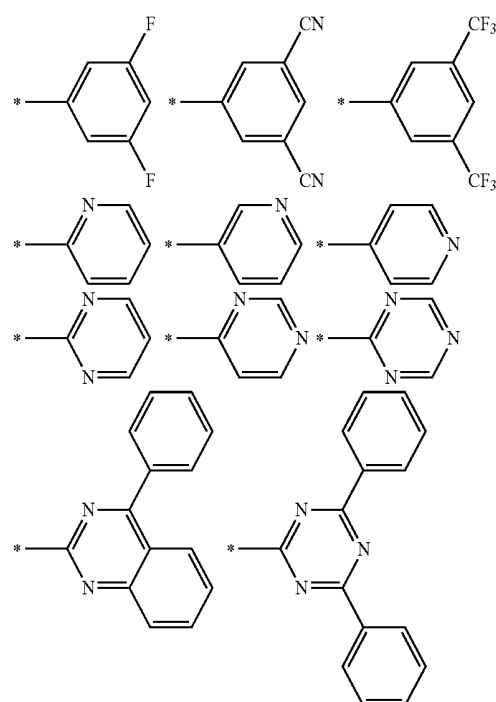
g_5 is an integer from 0 to 5,

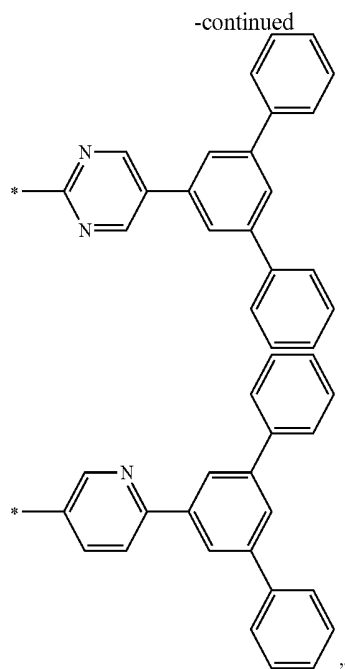
g_6 is an integer from 0 to 6, and

* indicates a binding site to a neighboring atom.

7. The heterocyclic compound of claim 1, wherein:

R_2 is selected from the following structures:





wherein, in the above structures,

* indicates a binding site to a neighboring atom.

8. The heterocyclic compound of claim 1, wherein:

R_3 to R_{10} are each independently selected from:

hydrogen, deuterium, a phenyl group, a naphthyl group, a fluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a biphenyl group, and a terphenyl group; and

a phenyl group, a naphthyl group, a fluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, —Si(Q_{31})(Q_{32})(Q_{33}), a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenyle-

nyl group, a pyridinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a biphenyl group, and a terphenyl group, 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_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryl group substituted with a C_1 - C_{60} alkyl group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

9. The heterocyclic compound of claim 1, wherein:

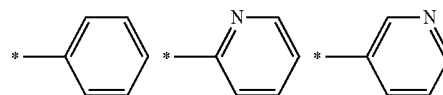
at least one of R_4 and R_9 is selected from:

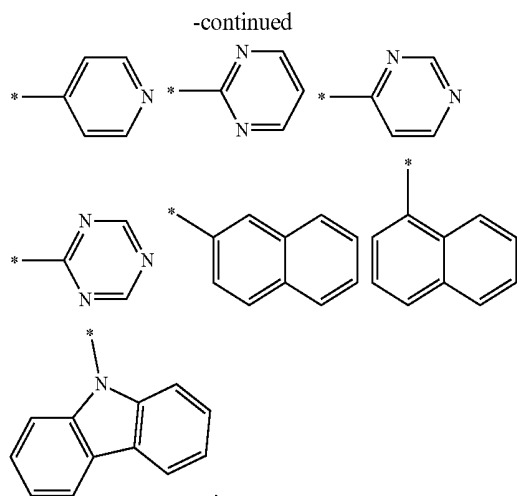
a phenyl group, a naphthyl group, a fluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a biphenyl group, and a terphenyl group; and

a phenyl group, a naphthyl group, a fluorenyl group, a pyrenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a triazinyl group, a biphenyl group, and a terphenyl group.

10. The heterocyclic compound of claim 1, wherein:

R_4 and R_9 are each independently selected from the following structures:



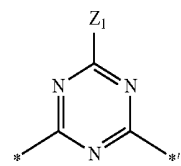
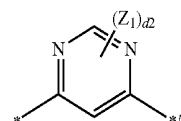
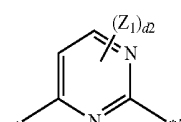
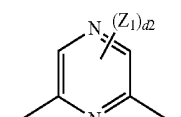
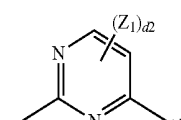
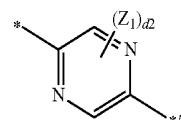
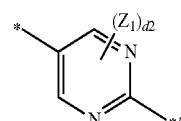
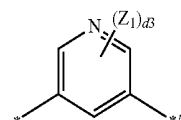
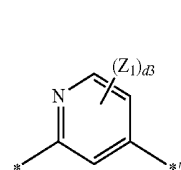
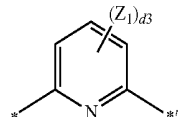
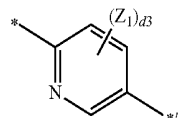
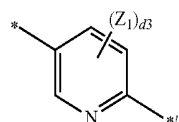
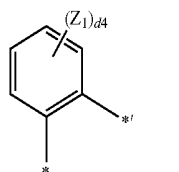
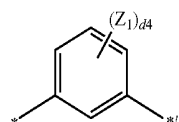
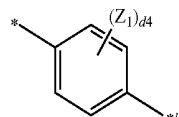


wherein, in the above structures,

* indicates a binding site to a neighboring atom.

11. The heterocyclic compound of claim 1, wherein:

L_1 is selected from groups represented by Formulae 3-1 to 3-15:



wherein, in Formulae 3-1 to 3-15,

Z_1 is selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, 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 benzo-fluorenyl group, a dibenzofluorenyl group, a phenanthrenyl

group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuran group, a dibenzothiophenyl group, a triazinyl group, a benzimidazolyl group, a phenanthrolinyl group, a biphenyl group, and a terphenyl group,

d2 is an integer from 0 to 2,

d3 is an integer from 0 to 3,

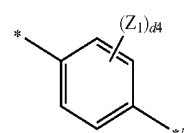
d4 is an integer from 0 to 4, and

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

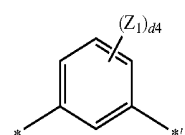
12. The heterocyclic compound of claim 1, wherein:

L₂ is selected from groups represented by Formulae 3-1 to 3-58;

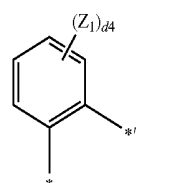
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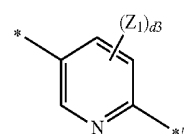
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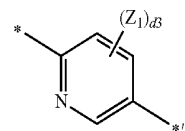
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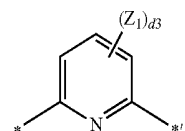
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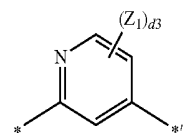
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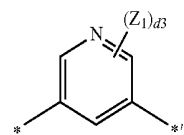
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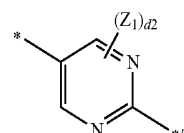
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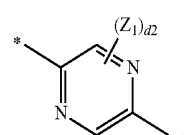
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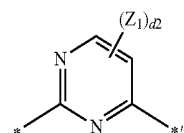
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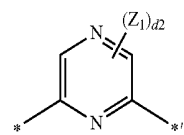
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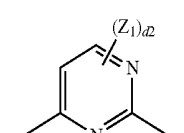
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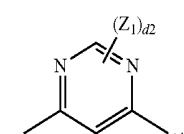
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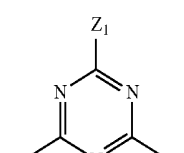
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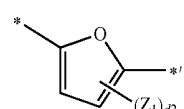
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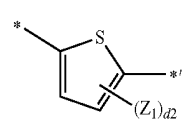
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3-15

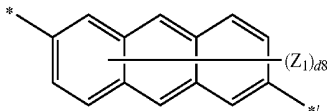
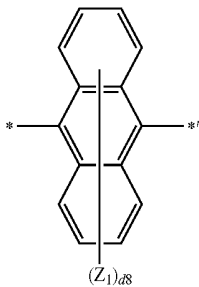
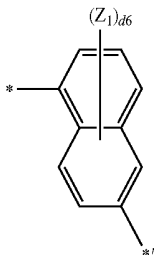
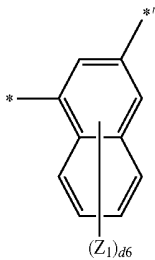
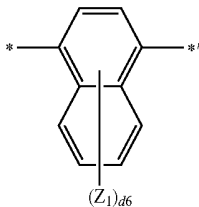
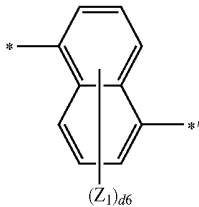
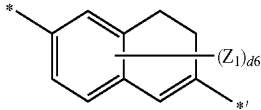


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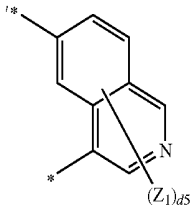
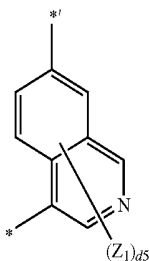
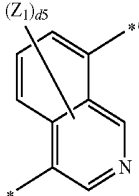
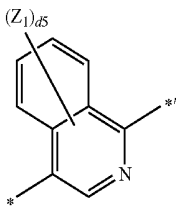
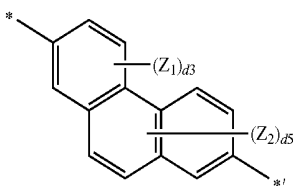
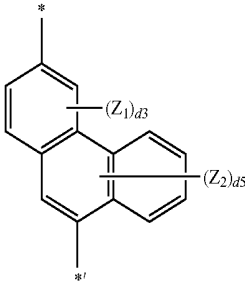


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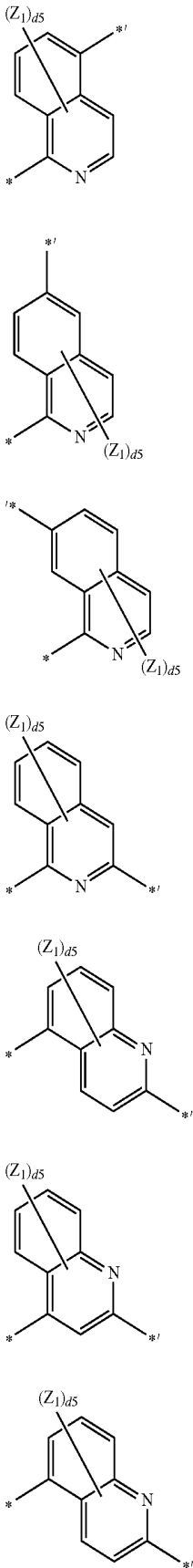
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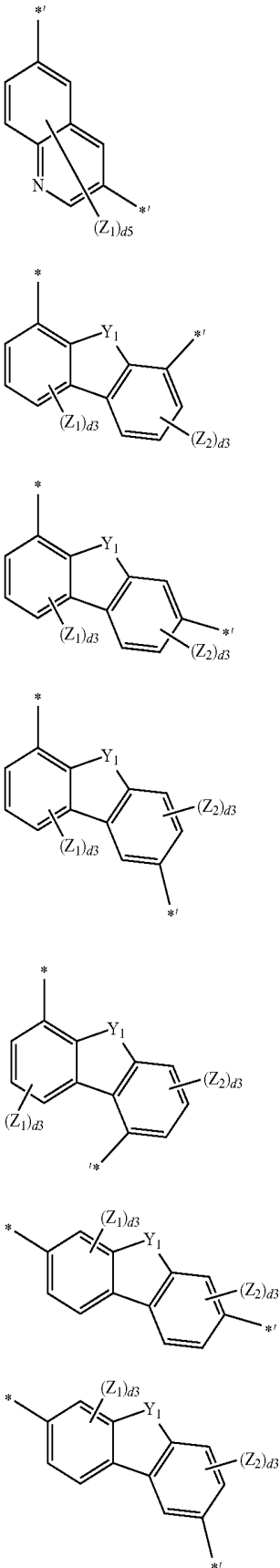
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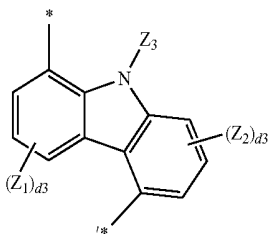
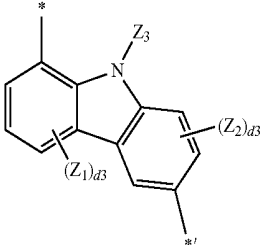
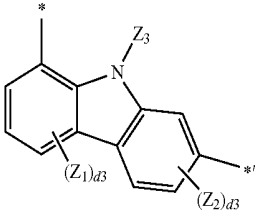
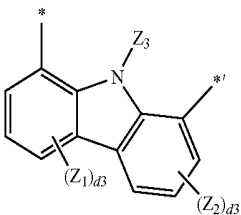
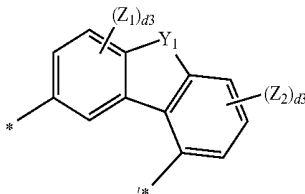
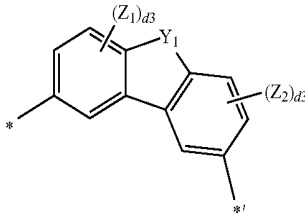
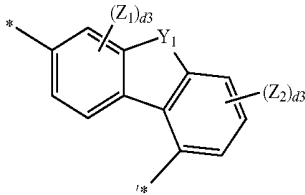
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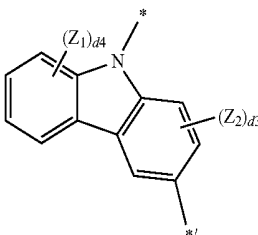
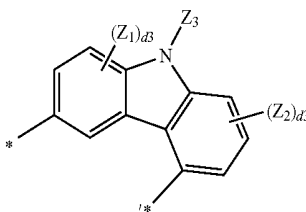
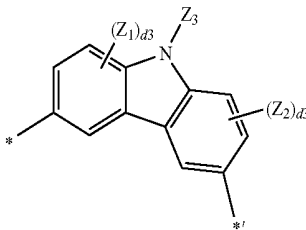
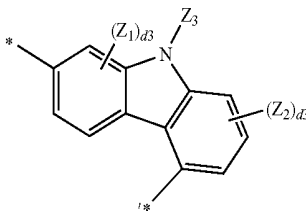
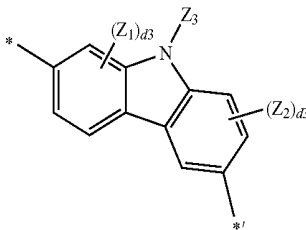
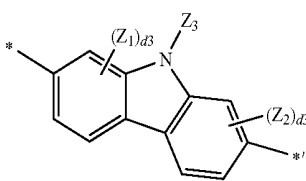
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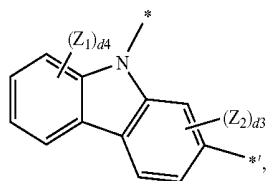


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3-58



wherein, in Formulae 3-1 to 3-58,

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

Z_1 to Z_7 are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, 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 pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a triazinyl group, a benzimidazolyl group, a phenanthrolinyl group, a biphenyl group, and a terphenyl group,

Z_3 and Z_4 are optionally linked to form a Spiro structure,

Z_6 and Z_7 are optionally linked to form a Spiro structure,

d_2 is an integer from 0 to 2,

d_3 is an integer from 0 to 3,

d_4 is an integer from 0 to 4,

d_5 is an integer from 0 to 5,

d_6 is an integer from 0 to 6,

d_8 is an integer from 0 to 8, and

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

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, the organic layer comprising an emission

layer and at least one of the heterocyclic 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 at least one selected from a hole injection layer, a hole transport layer, a buffer layer, an emission auxiliary layer, and an electron blocking layer, and

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

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

the emission layer comprises the heterocyclic compound.

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

the emission layer further comprises a phosphine oxide-based compound.

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

the hole blocking layer comprises a phosphine oxide-based compound.

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

the hole transport region comprises a charge-generation material.

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

the hole blocking layer comprises the heterocyclic compound.

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

the electron transport layer comprises the heterocyclic compound.

* * * * *

专利名称(译)	异环化合物和有机发光装置，包括相同的装置		
公开(公告)号	US20180240980A1	公开(公告)日	2018-08-23
申请号	US15/870360	申请日	2018-01-12
[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. 产学合作基础庆尚大学		
当前申请(专利权)人(译)	三星DISPLAY CO. , LTD. 产学合作基础庆尚大学		
[标]发明人	KIM MIKYUNG KIM YUNHI KWON SOONKI BAEK JANGYEOL		
发明人	KIM, MIKYUNG KIM, YUNHI KWON, SOONKI BAEK, JANGYEOL		
IPC分类号	H01L51/00 C07F9/6584 C09K11/02 C09K11/06		
CPC分类号	H01L51/0067 C07F9/6584 C09K11/025 C09K11/06 H01L51/0071 H01L51/0085 H01L51/5016 H01L51/5096 H01L51/5072 H01L51/5092 C09K2211/185 C09K2211/1007 C09K2211/1029 H01L51/5012		
优先权	1020170021727 2017-02-17 KR		
外部链接	Espacenet USPTO		

摘要(译)

提供杂环化合物和包含其的有机发光装置。杂环化合物可以由式1表示。式1的取代基和变量可以如本公开中所定义。包含由式1表示的杂环化合物的有机发光装置可以具有低驱动电压，高电流密度和高效率。

