



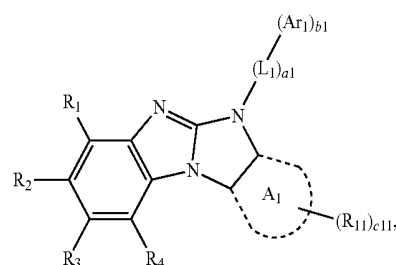
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(19) **United States**(12) **Patent Application Publication**
LEE et al.(10) **Pub. No.: US 2018/0019406 A1**(43) **Pub. Date: Jan. 18, 2018**(54) **HETEROCYCLIC COMPOUND AND
ORGANIC LIGHT-EMITTING DEVICE
INCLUDING THE SAME**(52) **U.S. CL.**CPC *H01L 51/0072* (2013.01); *H01L 51/0071*
(2013.01); *C07D 487/04* (2013.01); *C07D*
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51/0067 (2013.01); *H01L 51/0052* (2013.01);
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SIM, Yongin-si (KR); **Eunjae JEONG**,
Yongin-si (KR); **Seokhwan HWANG**,
Yongin-si (KR)(57) **ABSTRACT**

A heterocyclic compound is represented by Formula 1:

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C07D 471/14 (2006.01)
C07D 487/04 (2006.01)
C07D 491/147 (2006.01)

<Formula 1>

wherein, in Formula 1, R_1 to R_4 , R_{11} , ring A_1 , L_1 , Ar_1 , c_{11} , a_1 , and b_1 are as defined in the specification.**40****220****190****150****110****210**

FIG. 1

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FIG. 2

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FIG. 3

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FIG. 4

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HETEROCYCLIC COMPOUND AND ORGANIC LIGHT-EMITTING DEVICE INCLUDING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

[0001] Korean Patent Application No. 10-2016-0090775, filed on Jul. 18, 2016, in the Korean Intellectual Property Office, and entitled: "Heterocyclic Compound and Organic Light-Emitting Device Including the Same," is incorporated by reference herein in its entirety.

BACKGROUND

1. Field

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

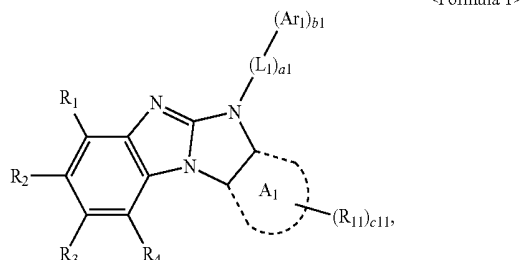
2. Description of the Related Art

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

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

SUMMARY

[0005] Embodiments are directed to a heterocyclic compound represented by Formula 1:



[0006] wherein, in Formula 1,

[0007] ring A₁ may be a C₁₀-C₆₀ carbocyclic group or a C₆-C₆₀ heterocyclic group,

[0008] L₁ may be selected from a substituted or unsubstituted C₃-C₆₀ carbocyclic group, a substituted or unsubstituted C₁-C₆₀ heterocyclic group, *—S(=O)—*, *—S(=O)₂—*, *—P(=O)(Q₄)—*, and *—P(=S)(Q₄)—*,

[0009] a₁ may be an integer selected from 0 to 5, wherein, when a₁ is two or more, two or more L₁(s) may be identical to or different from each other,

[0010] Ar₁ may be selected from a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —S(=O)(Q₁), —S(=O)₂(Q₁), —P(=O)(Q₁)(Q₂), and —P(=S)(Q₁)(Q₂),

[0011] b₁ may be an integer selected from 1 to 5, wherein, when b₁ is two or more, two or more Ar₁(s) may be identical to or different from each other,

[0012] R₁ to R₄ and R₁₁ may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₂-C₆₀ alkenyl group, a substituted or unsubstituted C₂-C₆₀ alkynyl group, a substituted or unsubstituted C₁-C₆₀ alkoxy group, a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(Q₁)(Q₂)(Q₃), —N(Q₁)(Q₂), —B(Q₁)(Q₂), —C(=O)(Q₁), —S(=O)₂(Q₁), and —P(=O)(Q₁)(Q₂),

[0013] c₁₁ may be an integer selected from 0 to 6, wherein, when c₁₁ is two or more, two or more R₁₁(s) may be identical to or different from each other,

[0014] at least one substituent selected from a substituent (s) of the substituted C₁₀-C₆₀ carbocyclic group, the substituted C₆-C₆₀ heterocyclic group, the substituted C₃-C₆₀ carbocyclic group, the substituted C₁-C₆₀ heterocyclic group, the substituted C₁-C₆₀ alkyl group, the substituted C₂-C₆₀ alkenyl group, the substituted C₂-C₆₀ alkynyl group, the substituted C₁-C₆₀ alkoxy group, the substituted C₃-C₁₀ cycloalkyl group, the substituted C₁-C₁₀ heterocycloalkyl group, the substituted C₃-C₁₀ cycloalkenyl group, the substituted C₁-C₁₀ heterocycloalkenyl group, the substituted C₆-C₆₀ aryl group, the substituted C₆-C₆₀ aryloxy group, the substituted C₆-C₆₀ arylthio group, the substituted C₁-C₆₀ heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from:

[0015] deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group;

[0016] a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazino group, a hydrazono group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —Si(Q₁₁)(Q₁₂)(Q₁₃), —N(Q₁₁)(Q₁₂), —B(Q₁₁)(Q₁₂), —C(=O)(Q₁₁), —S(=O)₂(Q₁₁), and —P(=O)(Q₁₁)(Q₁₂);

[0017] 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;

[0018] a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, a terphenyl group, —Si(Q₂₁)(Q₂₂)(Q₂₃), —N(Q₂₁)(Q₂₂), —B(Q₂₁)(Q₂₂), —C(=O)(Q₂₁), —S(=O)₂(Q₂₁), and —P(=O)(Q₂₁)(Q₂₂); and

[0019] —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂).

[0020] Q₁ to Q₄, 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 amino group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, and

[0021] * and *' each indicate a binding site to a neighboring atom.

[0022] 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 that is disposed between the first electrode and the second

electrode and includes an emission layer, wherein the organic layer includes at least one of the heterocyclic compound provided above.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] Features will become apparent to those of skill in the art by describing in detail exemplary embodiments with reference to the attached drawings in which:

[0024] FIG. 1 illustrates a schematic view of an organic light-emitting device according to an embodiment;

[0025] FIG. 2 illustrates a schematic view of an organic light-emitting device according to an embodiment;

[0026] FIG. 3 illustrates a schematic view of an organic light-emitting device according to an embodiment; and

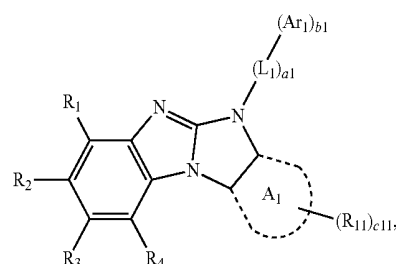
[0027] FIG. 4 illustrates a schematic view of an organic light-emitting device according to an embodiment.

DETAILED DESCRIPTION

[0028] Example embodiments will now be described more fully hereinafter with reference to the accompanying drawings; however, they may be embodied in different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey exemplary implementations to those skilled in the art.

[0029] In the drawing figures, the dimensions of layers and regions may be exaggerated for clarity of illustration. It will also be understood that when a layer or element is referred to as being “on” another layer or substrate, it can be directly on the other layer or substrate, or intervening layers may also be present. In addition, it will also be understood that when a layer is referred to as being “between” two layers, it can be the only layer between the two layers, or one or more intervening layers may also be present. Like reference numerals refer to like elements throughout.

[0030] A heterocyclic compound according to an embodiment may be represented by Formula 1:



<Formula 1>

[0031] wherein, in Formula 1,

[0032] ring A₁ may be a C₁₀-C₆₀ carbocyclic group or a C₆-C₆₀ heterocyclic group.

[0033] In one or more embodiments, ring A₁ may be a C₁₀-C₆₀ carbocyclic group with two or more rings condensed with each other or a C₆-C₆₀ heterocyclic group with two or more rings condensed with each other.

[0034] In one or more embodiments, ring A₁ may be a naphthalene, a fluorene, a benzofluorene, a phenanthrene, an anthracene, a quinoline, an isoquinoline, a benzoquinoline, a carbazole, a dibenzofuran, a dibenzothiophene, or a benzocarbazolyl.

[0035] In one or more embodiments, ring A_1 may be a naphthalene, a phenanthrene, a quinoline, or a dibenzofuran, as examples.

[0036] L_1 in Formula 1 may be selected from a substituted or unsubstituted C_3 - C_{60} carbocyclic group, a substituted or unsubstituted C_1 - C_{60} heterocyclic group, $*-S(S=O)-*$, $*-S(=O)_2-*$, $*-P(=O)(Q_4)-*$, and $*-P(=S)(Q_4)-*$,

[0037] In one or more embodiments, L_1 may be selected from:

[0038] a benzene group, a pentalene group, an indene group, a naphthalene group, an azulene group, a heptalene group, an indacene group, an acenaphthalene group, a fluorene group, a spiro-bifluorene group, a spiro-benzofluorene-fluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pyrrole group, a thiophene group, a furan group, a silole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a triazine group, a benzofuran group, a benzothiophene group, a benzosilole group, a dibenzofuran group, a dibenzothiophene group, a dibenzosilole group, a carbazole group, a benzocarbazole group, a dibenzocarbazole group, a benzimidazole group, and an imidazopyridine group;

[0039] a benzene group, a pentalene group, an indene group, a naphthalene group, an azulene group, a heptalene group, an indacene group, an acenaphthalene group, a fluorene group, a spiro-bifluorene group, a spiro-benzofluorene-fluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pyrrole group, a thiophene group, a furan group, a silole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a triazine group, a benzofuran group, a benzothiophene group, a benzosilole group, a dibenzofuran group, a dibenzothiophene group, a dibenzosilole group, a carbazole group, a benzocarbazole group, a dibenzocarbazole group, a benzimidazole group, and an imidazopyridine group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a carbazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a benzofuranyl group, a benzo-

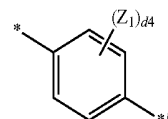
thiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, $-Si(Q_{31})(Q_{32})(Q_{33})$, $-N(Q_{31})(Q_{32})$, and $-B(Q_{31})(Q_{32})$; and

[0040] $*-S(=O)-*$, $*-S(=O)_2-*$, $*-P(=O)(Q_4)-*$, and $*-P(=S)(Q_4)-*$,

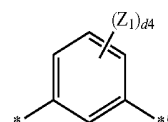
[0041] Q_4 and Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, and

[0042] $*$ and $*$ each indicate a binding site to a neighboring atom.

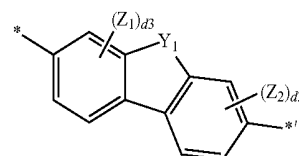
[0043] In one or more embodiments, L_1 may be selected from groups represented by Formulae 3-1 to 3-51, as examples:



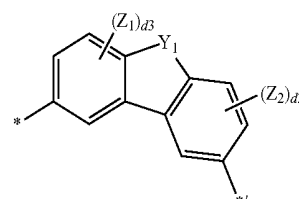
Formula 3-1



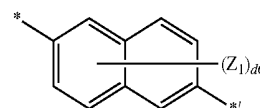
Formula 3-2



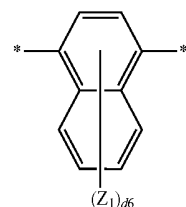
Formula 3-3



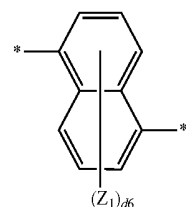
Formula 3-4



Formula 3-5

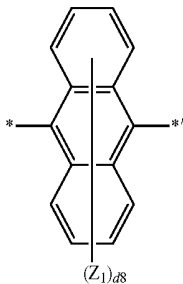


Formula 3-6



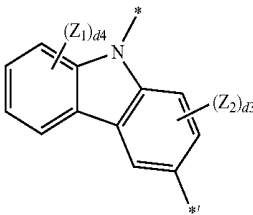
Formula 3-7

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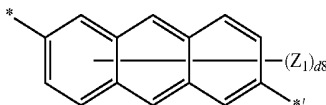
Formula 3-8

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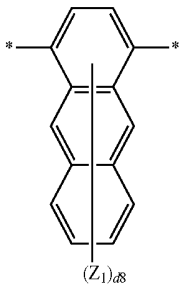
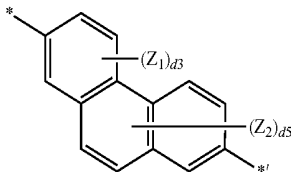


Formula 3-16

Formula 3-9

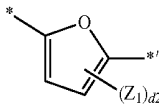


Formula 3-10

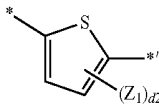


Formula 3-17

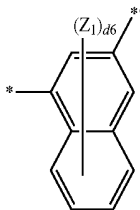
Formula 3-11



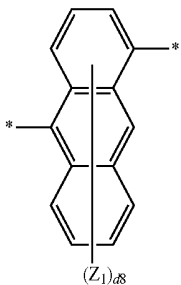
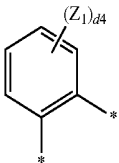
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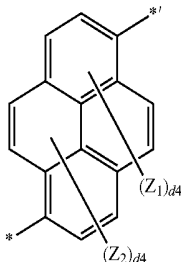
Formula 3-13



Formula 3-14

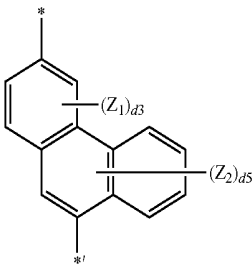


Formula 3-18

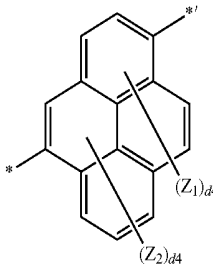


Formula 3-19

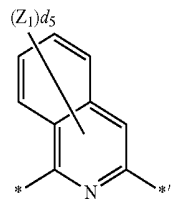
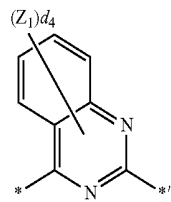
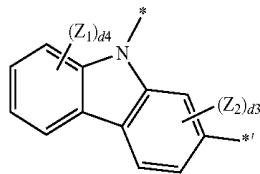
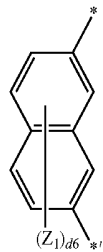
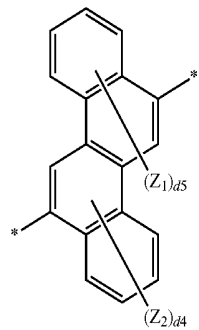
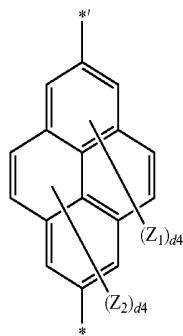
Formula 3-15



Formula 3-20



-continued



Formula 3-21

Formula 3-22

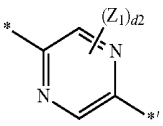
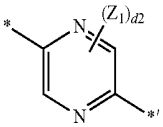
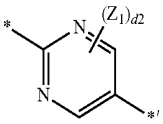
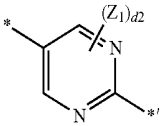
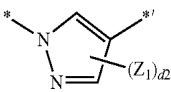
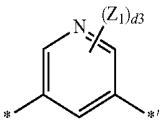
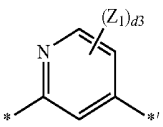
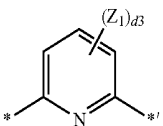
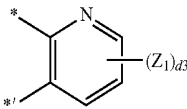
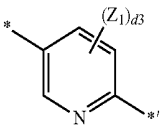
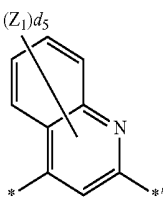
Formula 3-23

Formula 3-24

Formula 3-25

Formula 3-26

-continued



Formula 3-27

Formula 3-28

Formula 3-29

Formula 3-30

Formula 3-31

Formula 3-32

Formula 3-33

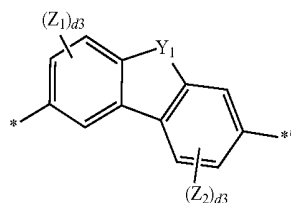
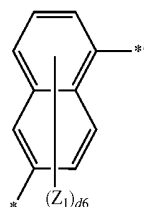
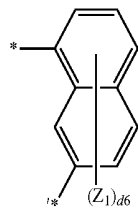
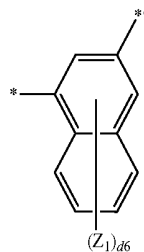
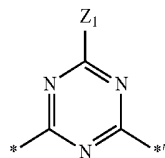
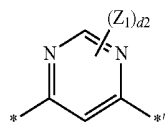
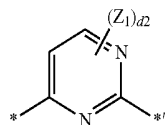
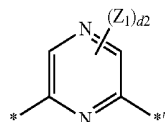
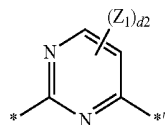
Formula 3-34

Formula 3-35

Formula 3-36

Formula 3-37

-continued



Formula 3-38

Formula 3-39

Formula 3-40

Formula 3-41

Formula 3-42

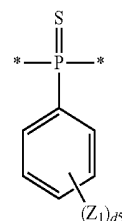
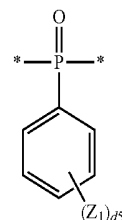
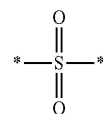
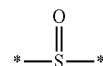
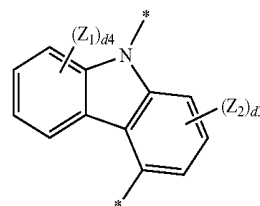
Formula 3-43

Formula 3-44

Formula 3-45

Formula 3-46

-continued



Formula 3-47

Formula 3-48

Formula 3-49

Formula 3-50

Formula 3-51

[0044] wherein, in Formulae 3-1 to 3-51,

[0045] Y_1 may be O, S, $C(Z_3)(Z_4)$, $N(Z_3)$, or $Si(Z_3)(Z_4)$;

[0046] Z_1 to Z_4 may each independently be selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkenyl group, a C_1 - C_{20} alkynyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, $-Si(Q_{31})(Q_{32})(Q_{33})$, $-N(Q_{31})(Q_{32})$, $-B(Q_{31})(Q_{32})$, $-C(=O)(Q_{31})$, $-S(=O)_2(Q_{31})$, and $-P(=O)(Q_{31})(Q_{32})$,

[0047] wherein Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group,

[0048] d_2 may be 1 or 2,[0049] d_3 may be an integer selected from 1 to 3,[0050] d_4 may be an integer selected from 1 to 4,[0051] d_5 may be an integer selected from 1 to 5,[0052] d_6 may be an integer selected from 1 to 6,[0053] d_8 may be an integer selected from 1 to 8, and

[0054] * and *' each indicate a binding site to a neighboring atom.

[0055] In one or more embodiments, L_1 may be selected from:

[0056] a benzene group, a naphthalene group, a fluorene group, a phenanthrene group, an anthracene group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a triazine group, a benzofuran group, a benzothiophene group, a benzosilole group, a dibenzofuran group, a dibenzothiophene group, a dibenzosilole group, and a carbazole group;

[0057] a benzene group, a naphthalene group, a fluorene group, a phenanthrene group, an anthracene group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a triazine group, a benzofuran group, a benzothiophene group, a benzosilole group, a dibenzofuran group, a dibenzothiophene group, a dibenzosilole group, and a carbazole group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, $-Si(Q_{31})(Q_{32})(Q_{33})$, $-N(Q_{31})(Q_{32})$, and $-B(Q_{31})(Q_{32})$; and

[0058] $*-S(=O)-*$, $*-S(=O)_2-*$, $*-P(=O)(Q_4)-*$, and $*-P(=S)(Q_4)-*$,

[0059] wherein Q_4 and Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, and

[0060] $*$ and $*$ ' each indicate a binding site to a neighboring atom.

[0061] In one or more embodiments, L_1 may be selected from:

[0062] a benzene group, a fluorene group, an anthracene group, a pyridine group, a triazine group, and a carbazole group;

[0063] a benzene group, a fluorene group, an anthracene group, a pyridine group, a triazine group, and a carbazole group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, $-Si(Q_{31})(Q_{32})(Q_{33})$, $-N(Q_{31})(Q_{32})$, and $-B(Q_{31})(Q_{32})$; and

[0064] $*-S(=O)-*$, $*-S(=O)_2-*$, $*-P(=O)(Q_4)-*$, and $*-P(=S)(Q_4)-*$,

[0065] wherein Q_4 and Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, and

[0066] $*$ and $*$ ' each indicate a binding site to a neighboring atom.

[0067] a_1 in Formula 1 may be an integer selected from 0 to 5. a_1 indicates the number of $L_1(s)$ in Formula 1, wherein, when a_1 is two or more, two or more $L_1(s)$ may be identical to or different from each other. For example, a_1 may be 0, 1, 2, or 3.

[0068] Ar_1 in Formula 1 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

tuted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, $-S(=O)(Q_1)$, $-S(=O)_2(Q_1)$, $-P(=O)(Q_1)(Q_2)$, and $-P(=S)(Q_1)(Q_2)$.

[0069] In one or more embodiments, Ar_1 may be selected from:

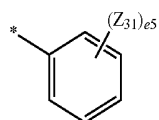
[0070] a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a thiophenyl group, a furanyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzonaphthofuranyl group, a dinaphthofuranyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a benzonaphthosilolyl group, a dinaphthosilolyl group, a benzimidazolyl group, a benzoimidazonaphthoimidazolyl group, and an imidazopyridinyl group;

[0071] a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a thiophenyl group, a furanyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzonaphthofuranyl group, a dinaphthofuranyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a benzonaphthosilolyl group, a dinaphthosilolyl group, a benzimidazolyl group, a benzoimidazonaphthoimidazolyl group, and an imidazopyridinyl group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a

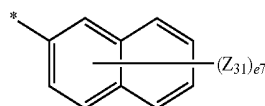
thiophenyl group, a furanyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, $-\text{N}(\text{Q}_{31})(\text{Q}_{32})$, and $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$; and
[0072] $-\text{S}(=\text{O})(\text{Q}_1)$, $-\text{S}(=\text{O})_2(\text{Q}_1)$, $-\text{P}(=\text{O})(\text{Q}_1)(\text{Q}_2)$, and $-\text{P}(=\text{S})(\text{Q}_1)(\text{Q}_2)$,

[0073] wherein Q_1 , Q_2 , and Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, as examples.

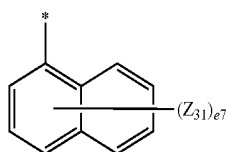
[0074] In one or more embodiments, Ar_1 may be selected from groups represented by Formulae 5-1 to 5-29, $-\text{S}(=\text{O})(\text{Q}_1)$, $-\text{S}(=\text{O})_2(\text{Q}_1)$, $-\text{P}(=\text{O})(\text{Q}_1)(\text{Q}_2)$, and $-\text{P}(=\text{S})(\text{Q}_1)(\text{Q}_2)$:



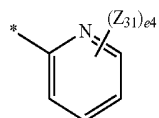
Formula 5-1



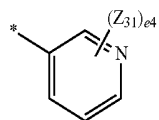
Formula 5-2



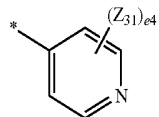
Formula 5-3



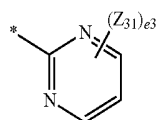
Formula 5-4



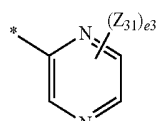
Formula 5-5



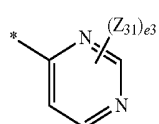
Formula 5-6



Formula 5-7

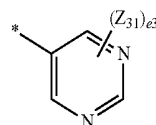


Formula 5-8

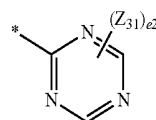


Formula 5-9

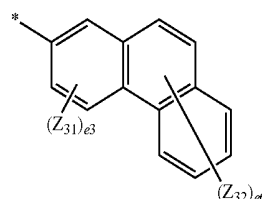
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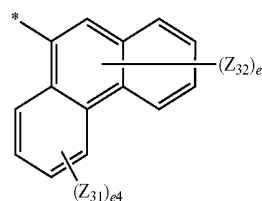
Formula 5-10



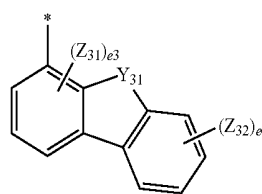
Formula 5-11



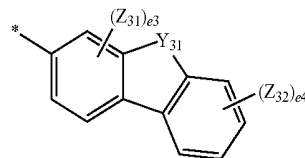
Formula 5-12



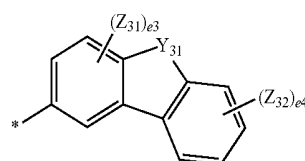
Formula 5-13



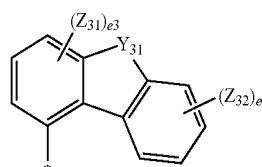
Formula 5-14



Formula 5-15

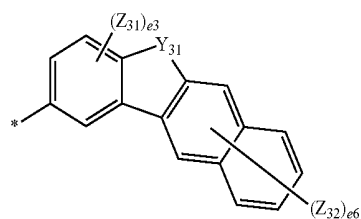
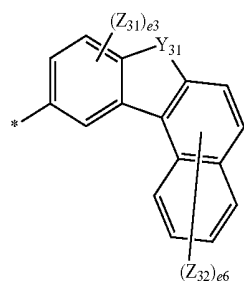
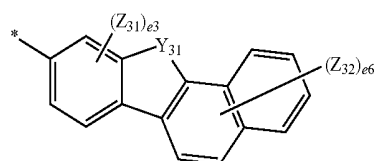
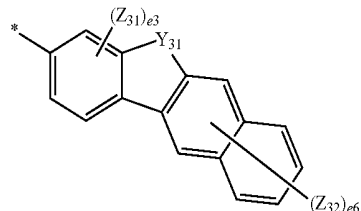
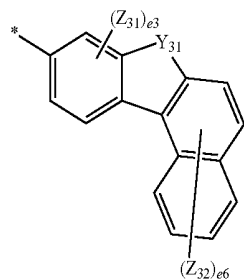
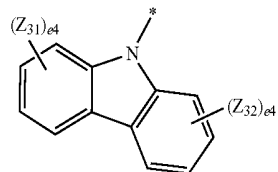
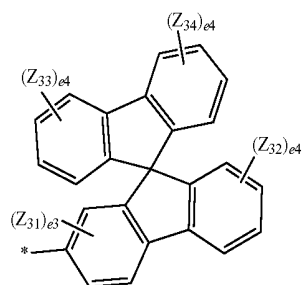


Formula 5-16



Formula 5-17

-continued



Formula 5-18

Formula 5-19

Formula 5-20

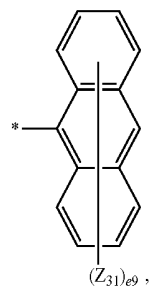
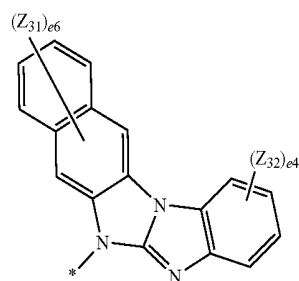
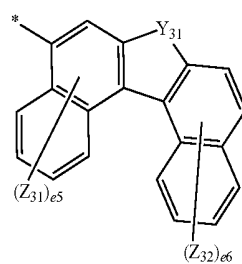
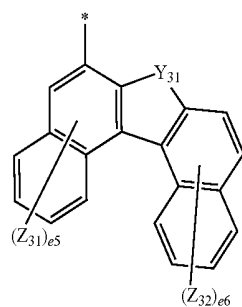
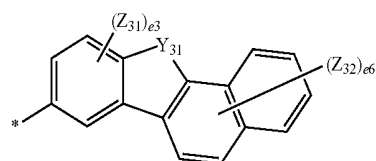
Formula 5-21

Formula 5-22

Formula 5-23

Formula 5-24

-continued



Formula 5-25

Formula 5-26

Formula 5-27

Formula 5-28

Formula 5-29

[0075] wherein, in Formulae 5-1 to 5-29,

[0076] Y₃₁ may be O, S, C(Z₃₅)(Z₃₆), N(Z₃₅), or Si(Z₃₅)(Z₃₆),

[0077] Z₃₁ to Z₃₆ 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 alkenyl group, a C₁-C₂₀ alkynyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a

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

[0078] wherein Q_1 , Q_2 , and Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group,

[0079] e_2 may be 1 or 2,

[0080] e_3 may be an integer selected from 1 to 3,

[0081] e_4 may be an integer selected from 1 to 4,

[0082] e_5 may be an integer selected from 1 to 5,

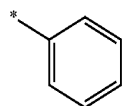
[0083] e_6 may be an integer selected from 1 to 6,

[0084] e_7 may be an integer selected from 1 to 7,

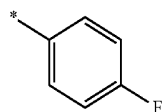
[0085] e_9 may be an integer selected from 1 to 9, and

[0086] * and *' each indicate a binding site to a neighboring atom.

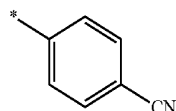
[0087] In one or more embodiments, Ar_1 may be selected from groups represented by Formulae 6-1 to 6-55, as examples:



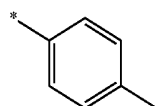
Formula 6-1



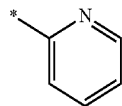
Formula 6-2



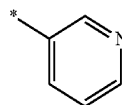
Formula 6-3



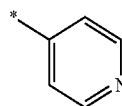
Formula 6-4



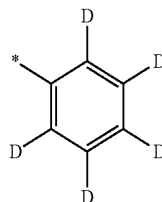
Formula 6-5



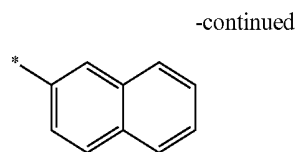
Formula 6-6



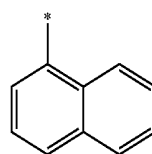
Formula 6-7



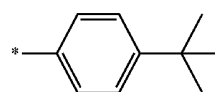
Formula 6-8



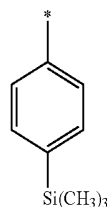
Formula 6-9



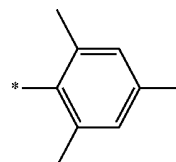
Formula 6-10



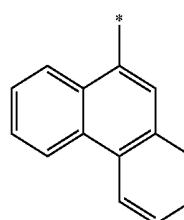
Formula 6-11



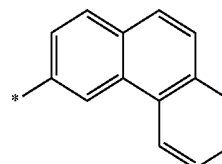
Formula 6-12



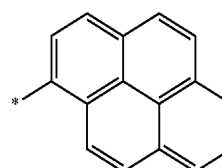
Formula 6-13



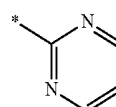
Formula 6-14



Formula 6-15

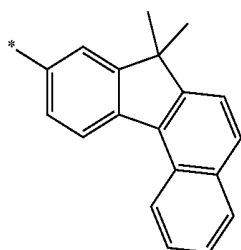
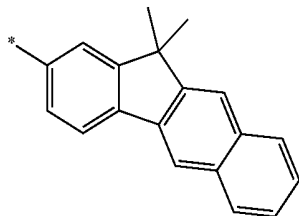
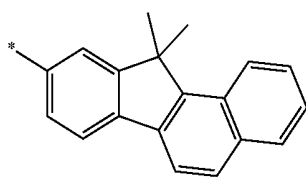
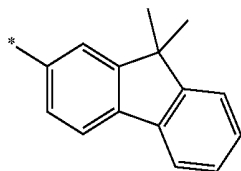
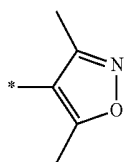
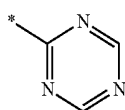
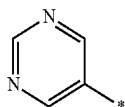
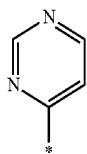


Formula 6-16



Formula 6-17

-continued



Formula 6-18

Formula 6-19

Formula 6-20

Formula 6-21

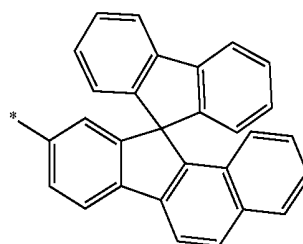
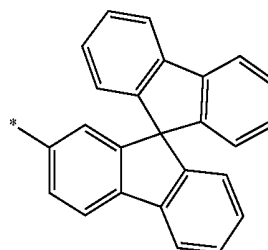
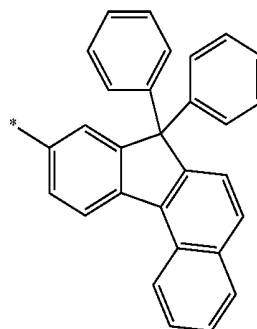
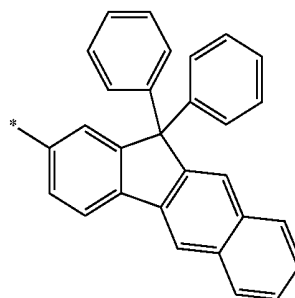
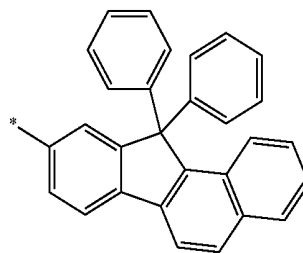
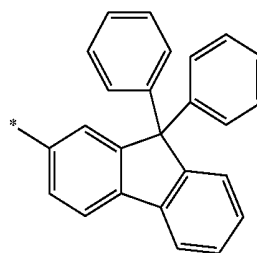
Formula 6-22

Formula 6-23

Formula 6-24

Formula 6-25

-continued



Formula 6-26

Formula 6-27

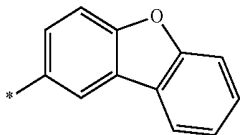
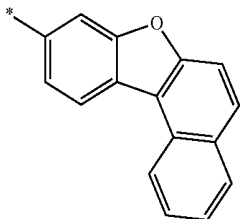
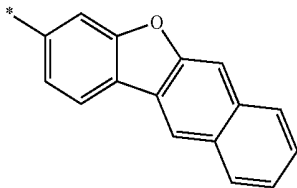
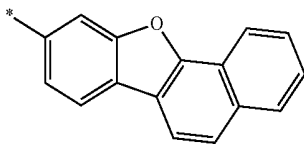
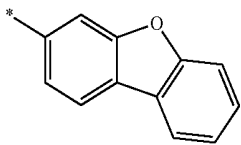
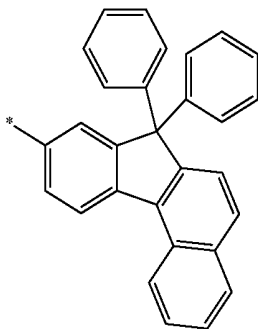
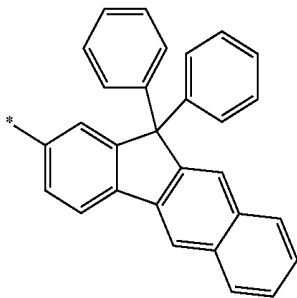
Formula 6-28

Formula 6-29

Formula 6-30

Formula 6-31

-continued



Formula 6-32

Formula 6-33

Formula 6-34

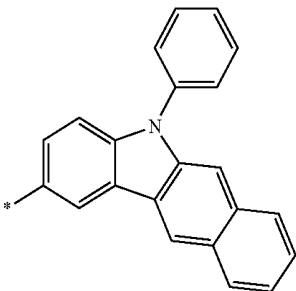
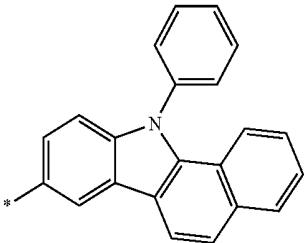
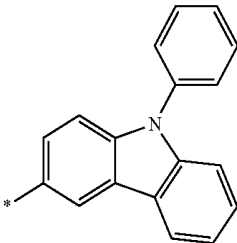
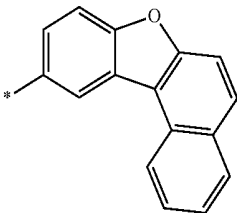
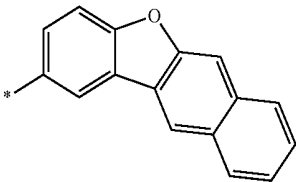
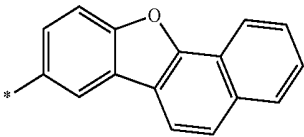
Formula 6-35

Formula 6-36

Formula 6-37

Formula 6-38

-continued



Formula 6-39

Formula 6-40

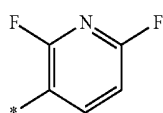
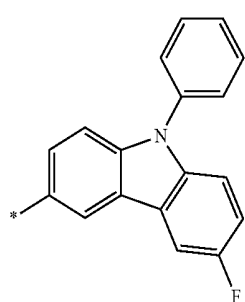
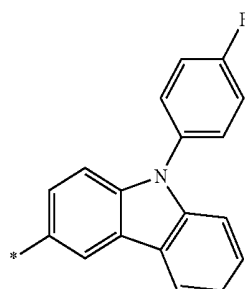
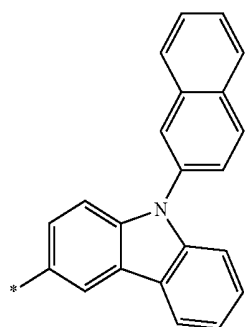
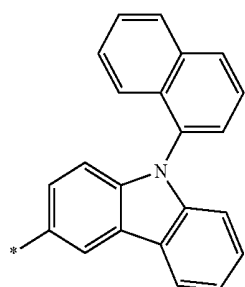
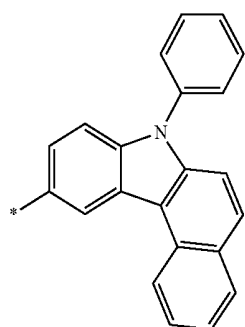
Formula 6-41

Formula 6-42

Formula 6-43

Formula 6-44

-continued



Formula 6-45

Formula 6-46

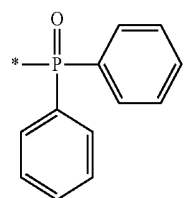
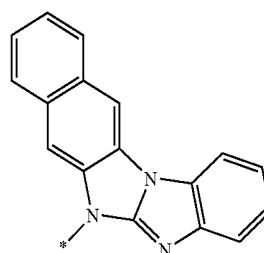
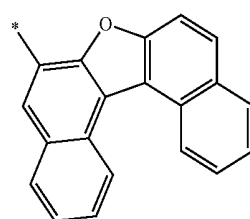
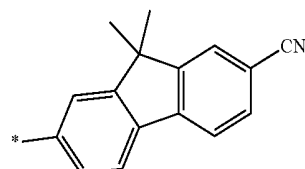
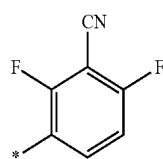
Formula 6-47

Formula 6-48

Formula 6-49

Formula 6-50

-continued



Formula 6-51

Formula 6-52

Formula 6-53

Formula 6-54

Formula 6-55

[0088] wherein * indicates a binding site to a neighboring atom.

[0089] In one or more embodiments, Ar₁ may be selected from:

[0090] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, a pyridinyl group, a dinaphthofuranyl group, and a benzoimidazonaphthoimidazolyl group;

[0091] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, a pyridinyl group, a dinaphthofuranyl group, and a benzoimidazonaphthoimidazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, —N(Q₃₁)(Q₃₂), and —Si(Q₃₁)(Q₃₂)(Q₃₃); and

[0092] —S(=O)(Q₁), —S(=O)₂(Q₁), —P(=O)(Q₁)(Q₂), and —P(=S)(Q₁)(Q₂).

[0093] wherein Q_1 , Q_2 , and Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0094] b_1 in Formula 1 may be an integer selected from 1 to 5. b_1 indicates the number of $Ar_1(s)$ in Formula 1, wherein, when b_1 is two or more, two or more $Ar_1(s)$ may be identical to or different from each other. For example, b_1 may be 1 or 2.

[0095] R_1 to R_4 and R_{11} in Formula 1 may each independently be selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1 - C_{60} alkyl group, a substituted or unsubstituted C_2 - C_{60} alkenyl group, a substituted or unsubstituted C_2 - C_{60} alkynyl group, a substituted or unsubstituted C_1 - C_{60} alkoxy group, a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6 - C_{60} aryl group, a substituted or unsubstituted C_6 - C_{60} aryloxy group, a substituted or unsubstituted C_6 - C_{60} arylthio group, a substituted or unsubstituted C_1 - C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, $-Si(Q_1)(Q_2)(Q_3)$, $-N(Q_1)(Q_2)$, $-B(Q_1)(Q_2)$, $-C(=O)(Q_1)$, $-S(=O)_2(Q_1)$, and $-P(=O)(Q_1)(Q_2)$.

[0096] In one or more embodiments, R_1 to R_4 may each independently be selected from:

[0097] hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

[0098] a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, and a nitro group;

[0099] $-Si(Q_1)(Q_2)(Q_3)$, $-N(Q_1)(Q_2)$, $-B(Q_1)(Q_2)$, $-C(=O)(Q_1)$, $-S(=O)_2(Q_1)$, and $-P(=O)(Q_1)(Q_2)$; and

[0100] groups represented by Formulae 5-1 to 5-29, and

[0101] R_{11} may be selected from:

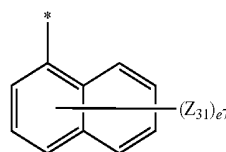
[0102] hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

[0103] a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, and a nitro group; and

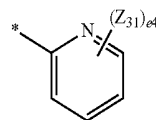
[0104] $-Si(Q_1)(Q_2)(Q_3)$, $-N(Q_1)(Q_2)$, $B(Q_1)(Q_2)$, $-C(=O)(Q_1)$, $-S(=O)_2(Q_1)$, and $-P(=O)(Q_1)(Q_2)$:

-continued

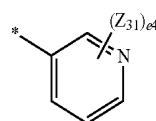
Formula 5-3



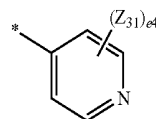
Formula 5-4



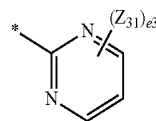
Formula 5-5



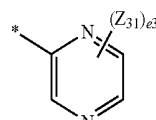
Formula 5-6



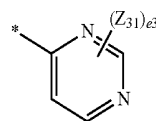
Formula 5-7



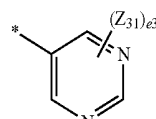
Formula 5-8



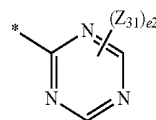
Formula 5-9



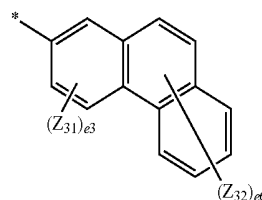
Formula 5-10



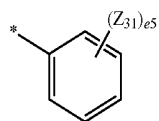
Formula 5-11



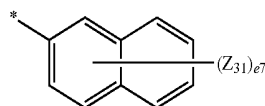
Formula 5-12



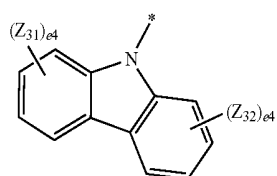
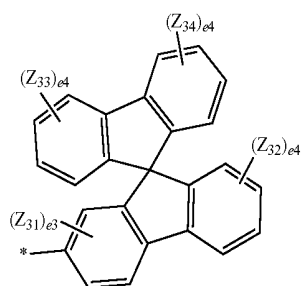
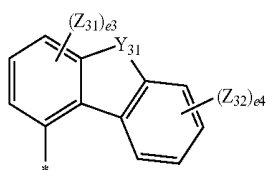
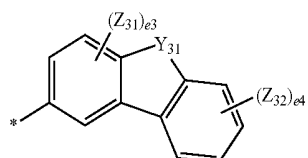
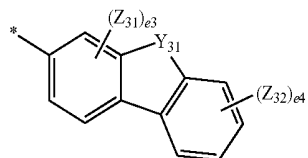
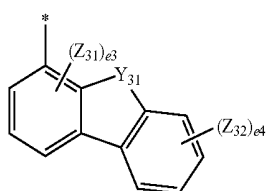
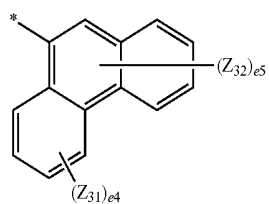
Formula 5-1



Formula 5-2

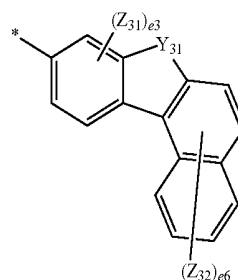


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Formula 5-13

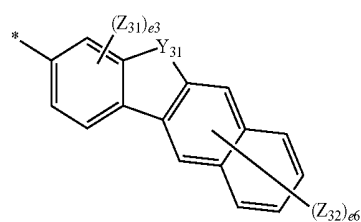
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Formula 5-14

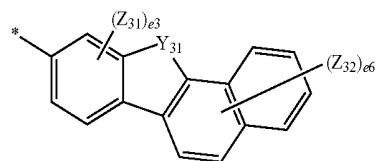
Formula 5-20

Formula 5-15



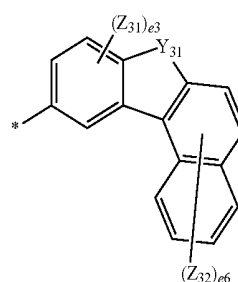
Formula 5-21

Formula 5-16



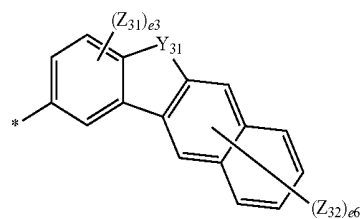
Formula 5-22

Formula 5-17



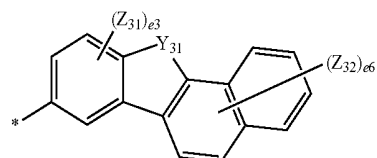
Formula 5-23

Formula 5-18



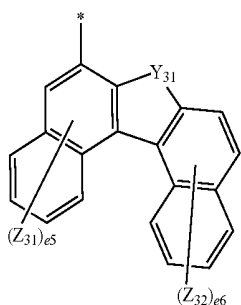
Formula 5-24

Formula 5-19

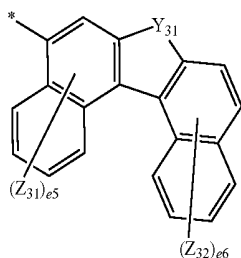


Formula 5-25

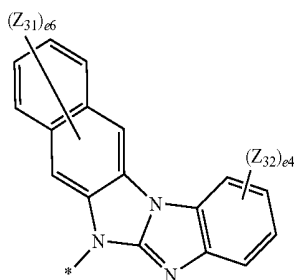
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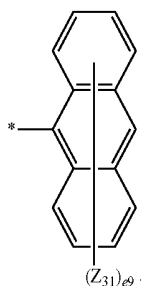
Formula 5-26



Formula 5-27



Formula 5-28



Formula 5-29

[0105] In Formulae 5-1 to 5-29,

[0106] Y_{31} may be O, S, $C(Z_{35})(Z_{36})$, $N(Z_{35})$, or $Si(Z_{35})(Z_{36})$.

[0107] Z_{31} to Z_{36} may each independently be selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkenyl group, a C_1 - C_{20} alkynyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, $-Si(Q_{31})(Q_{32})(Q_{33})$, $-N(Q_{31})(Q_{32})$, $-B(Q_{31})(Q_{32})$, $-C(=O)(Q_{31})$, $-S(=O)_2(Q_{31})$, and $-P(=O)(Q_{31})(Q_{32})$.

[0108] wherein Q_1 , Q_2 , and Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group,

[0109] e_2 may be 1 or 2,

[0110] e_3 may be an integer selected from 1 to 3,

[0111] e_4 may be an integer selected from 1 to 4,

[0112] e_5 may be an integer selected from 1 to 5,

[0113] e_6 may be an integer selected from 1 to 6,

[0114] e_7 may be an integer selected from 1 to 7,

[0115] e_9 may be an integer selected from 1 to 9, and

[0116] * and *¹ each indicate a binding site to a neighboring atom.

[0117] In one or more embodiments, R_1 to R_4 may each independently be selected from:

[0118] hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

[0119] a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, and a nitro group;

[0120] a phenyl group, a biphenyl group, a terphenyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyridinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

[0121] a phenyl group, a biphenyl group, a terphenyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyridinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, $-N(Q_{31})(Q_{32})$, and $-Si(Q_{31})(Q_{32})(Q_{33})$; and

[0122] $-Si(Q_1)(Q_2)(Q_3)$, $-N(Q_1)(Q_2)$, $-B(Q_1)(Q_2)$, $-C(=O)(Q_1)$, $-S(=O)_2(Q_1)$, and $-P(=O)(Q_1)(Q_2)$, and

[0123] R_{11} may be selected from:

[0124] hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

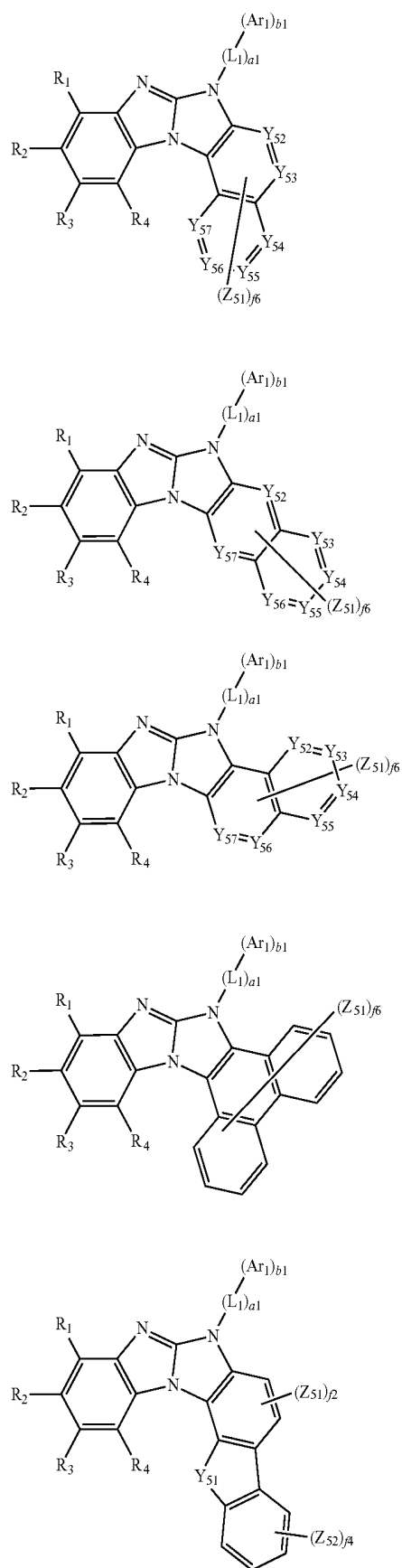
[0125] a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, and a nitro group; and

[0126] $-Si(Q_1)(Q_2)(Q_3)$, $-N(Q_1)(Q_2)$, $-B(Q_1)(Q_2)$, $-C(=O)(Q_1)$, $-S(=O)_2(Q_1)$, and $-P(=O)(Q_1)(Q_2)$.

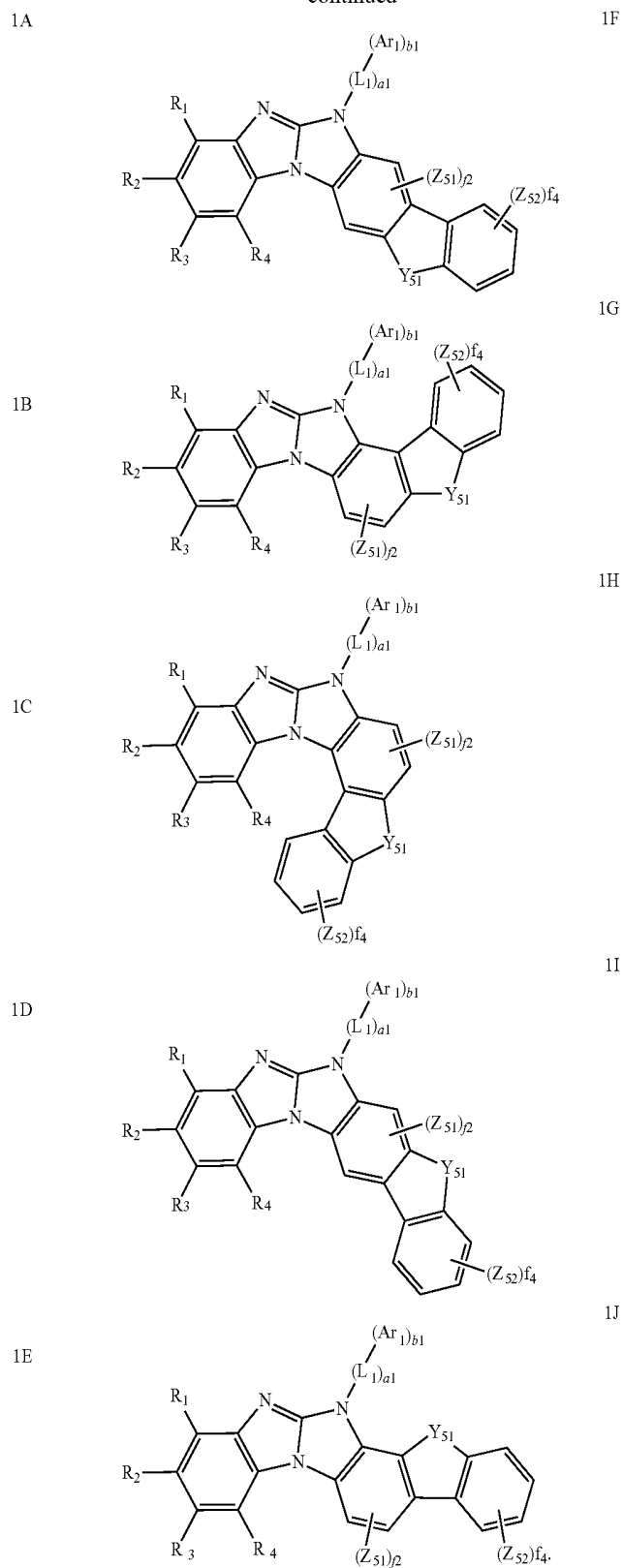
[0127] wherein Q_1 to Q_3 and Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, as examples.

[0128] c_{11} in Formula 1 may be an integer selected from 0 to 6. c_{11} indicates the number of $R_{11}(s)$ in Formula 1, wherein, when c_{11} is two or more, two or more $R_{11}(s)$ may be identical to or different from each other. For example, c_{11} may be 0, 1, or 2.

[0129] In one or more embodiments, the compound represented by Formula 1 may be represented by one selected from Formulae 1A to 1J:



-continued



[0130] In Formulae 1A to 1J, L_1 , a_1 , Ar_1 , b_1 , and R_1 to R_4 are the same as described above.

[0131] Y_{51} may be O, S, $C(Z_{53})(Z_{54})$, $N(Z_{53})$, or $Si(Z_{53})(Z_{54})$.

[0132] Y_{52} to Y_{57} may each independently be C(Z_{55}) or N,
 [0133] Z_{51} to Z_{55} 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, and a naphthyl group,

[0134] f2 may be 1 or 2,

[0135] f4 may be an integer selected from 1 to 4,

[0136] f6 may be an integer selected from 1 to 6, and

[0137] f8 may be an integer selected from 1 to 8.

[0138] In Formulae 1A to 1J,

[0139] L_1 may be selected from:

[0140] a benzene group, a fluorene group, an anthracene group, a pyridine group, a triazine group, and a carbazole group;

[0141] a benzene group, a fluorene group, an anthracene group, a pyridine group, a triazine group, and a carbazole group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, —Si(Q_{31})(Q_{32})(Q_{33}), —N(Q_{31})(Q_{32}), and —B(Q_{31})(Q_{32}); and

[0142] *—S(=O)—*, *—S(=O)₂—*, *—P(=O)(Q_4)—*, and *—P(=S)(Q_4)—*,

[0143] a1 may be an integer selected from 0 to 3,

[0144] Ar_1 may be selected from:

[0145] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, a pyridinyl group, a dinaphthofuranyl group, and a benzoimidazonaphthoimidazolyl group;

[0146] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, a pyridinyl group, a dinaphthofuranyl group, and a benzoimidazonaphthoimidazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, —N(Q_{31})(Q_{32}), and —Si(Q_{31})(Q_{32})(Q_{33}); and

[0147] —S(=O)(Q_1), —S(=O)₂(Q_1), —P(=O)(Q_1)(Q_2), and —P(=S)(Q_1)(Q_2),

[0148] b1 may be 1 or 2, and

[0149] R_1 to R_4 may each independently be selected from:

[0150] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

[0151] a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, and a nitro group;

[0152] a phenyl group, a biphenyl group, a terphenyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyridinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

[0153] a phenyl group, a biphenyl group, a terphenyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyridinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, —N(Q_{31})(Q_{32}), and —Si(Q_{31})(Q_{32})(Q_{33}); and

[0154] —Si(Q_1)(Q_2)(Q_3), —N(Q_1)(Q_2), —B(Q_1)(Q_2), —C(=O)(Q_1), —S(=O)₂(Q_1), and —P(=O)(Q_1)(Q_2),

[0155] wherein Q_1 to Q_4 and Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, as examples.

[0156] In one or more embodiments, in Formulae 1A to 1J,

[0157] R_1 , R_2 , and R_4 may each independently be selected from:

[0158] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

[0159] a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, and a nitro group; and

[0160] —Si(Q_1)(Q_2)(Q_3), —N(Q_1)(Q_2), —B(Q_1)(Q_2), —C(=O)(Q_1), —S(=O)₂(Q_1), and —P(=O)(Q_1)(Q_2), and

[0161] R_3 may be selected from:

[0162] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

[0163] a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, and a nitro group;

[0164] a phenyl group, a biphenyl group, a terphenyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyridinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

[0165] a phenyl group, a biphenyl group, a terphenyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyridinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, —N(Q_{31})(Q_{32}), and —Si(Q_{31})(Q_{32})(Q_{33}); and

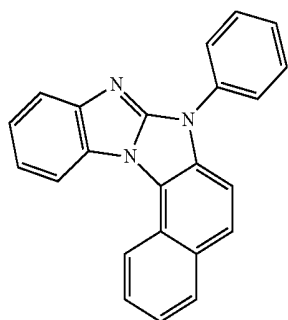
[0166] —Si(Q_1)(Q_2)(Q_3), —N(Q_1)(Q_2), —B(Q_1)(Q_2), —C(=O)(Q_1), —S(=O)₂(Q_1), and —P(=O)(Q_1)(Q_2),

[0167] wherein Q_1 to Q_3 and Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, as examples.

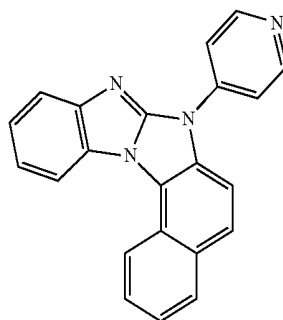
[0168] In one or more embodiments, the heterocyclic compound represented by Formula 1 may be one selected from Compounds 1 to 56:

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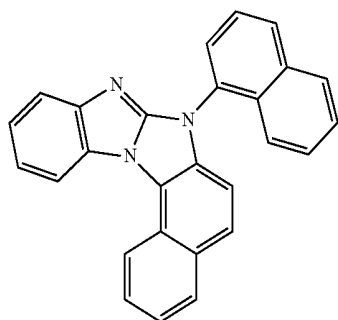
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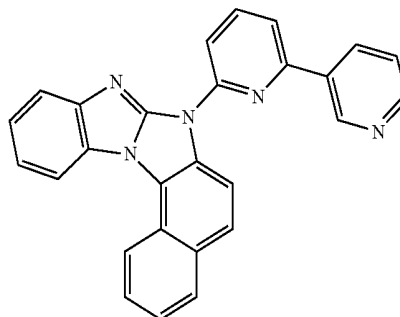
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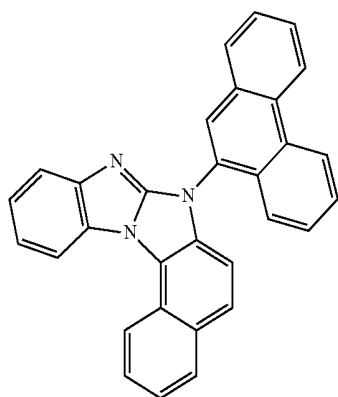
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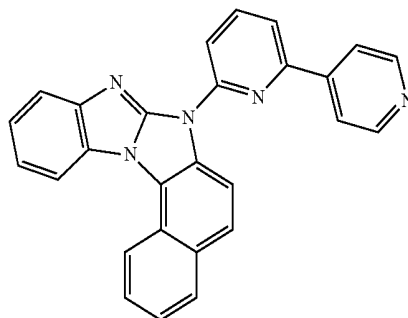
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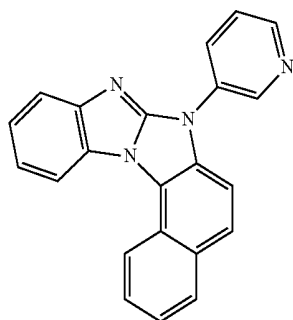
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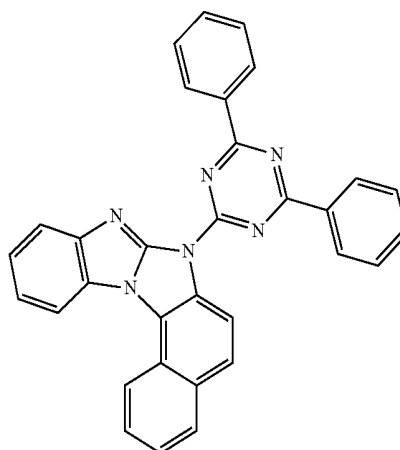
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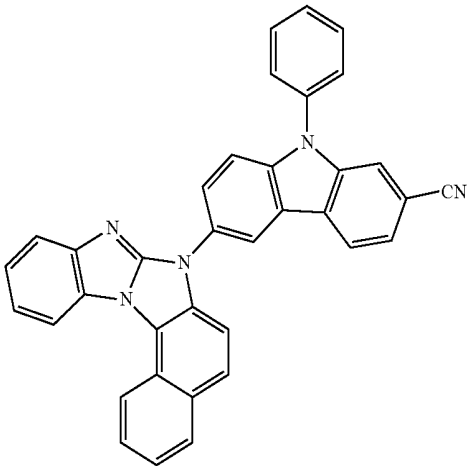
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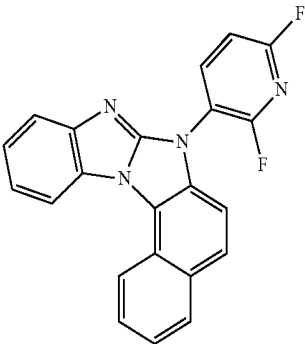


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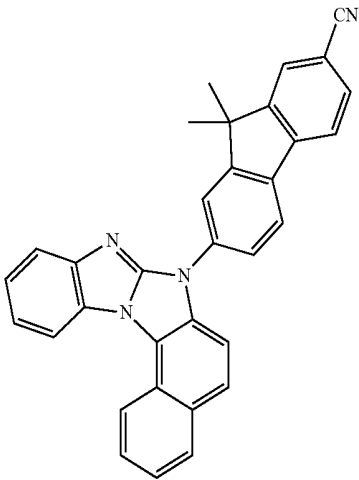


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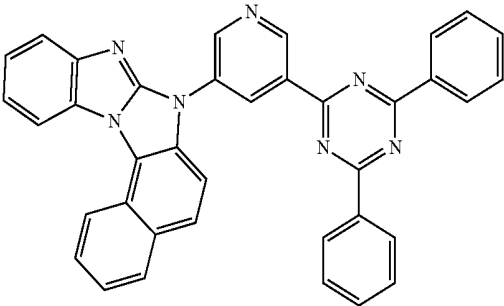
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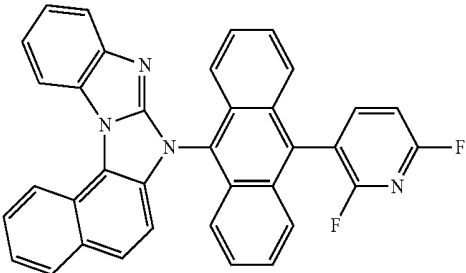
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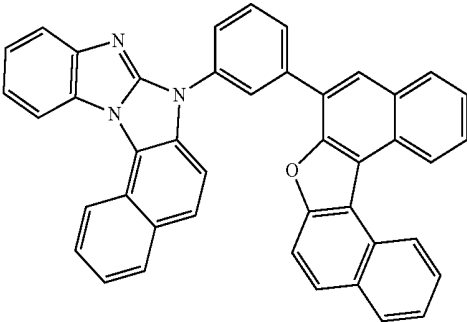
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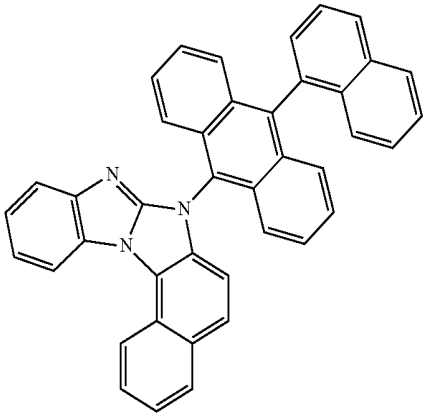
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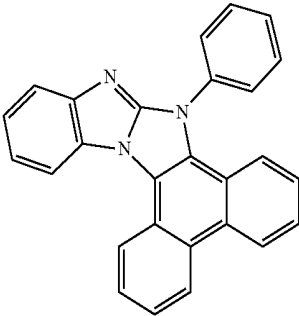
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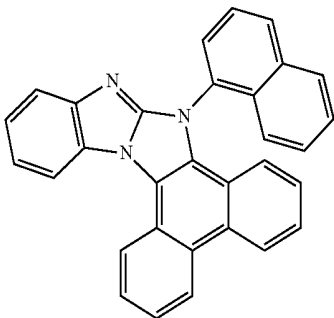


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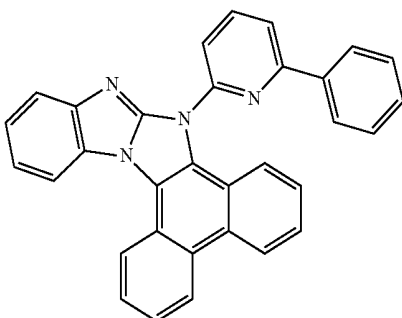
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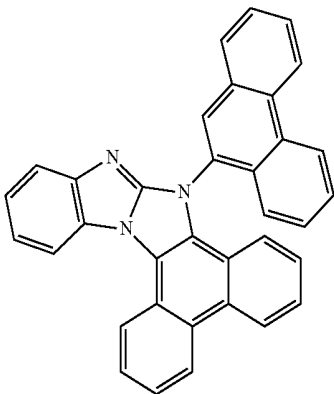


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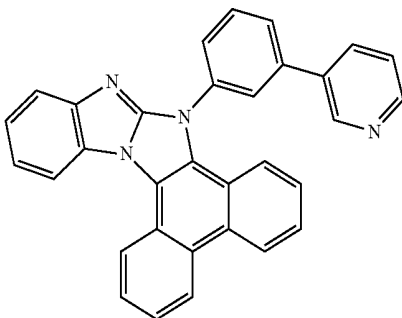
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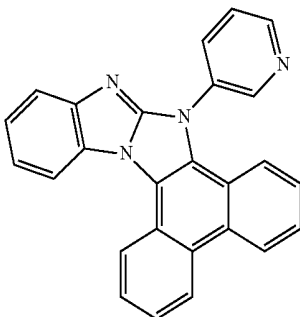
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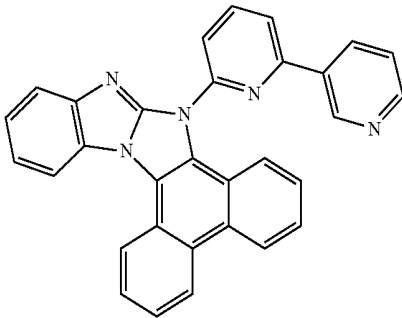
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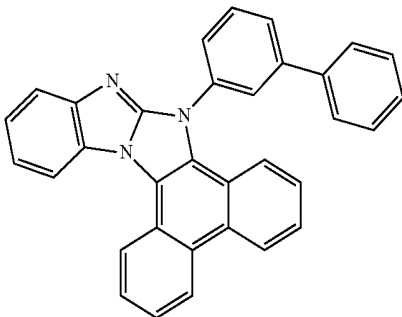
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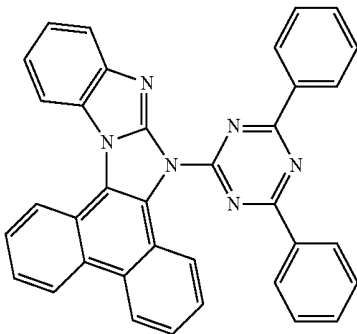
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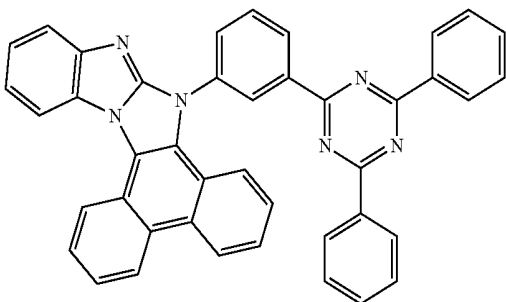
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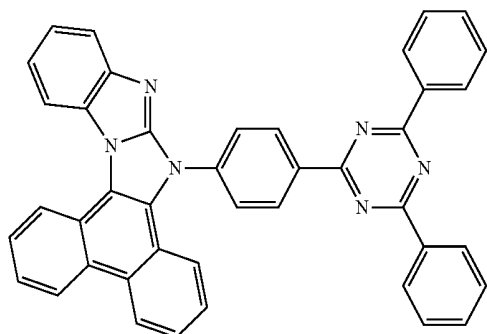
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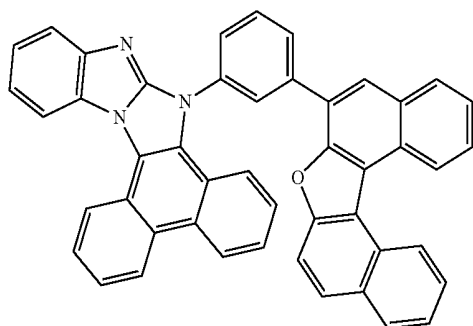
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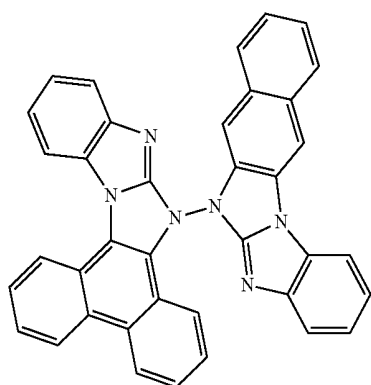
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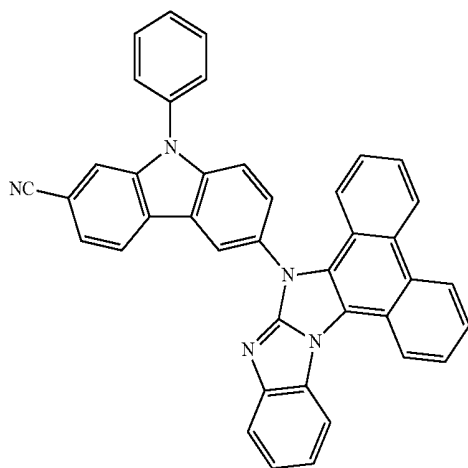
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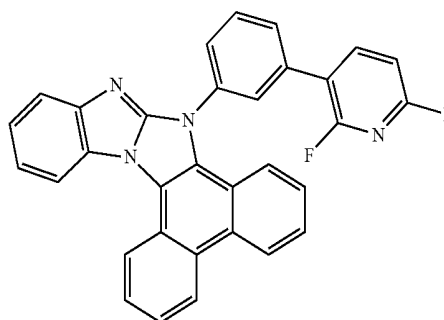


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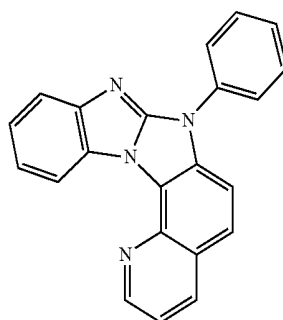


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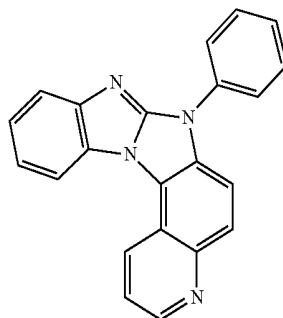
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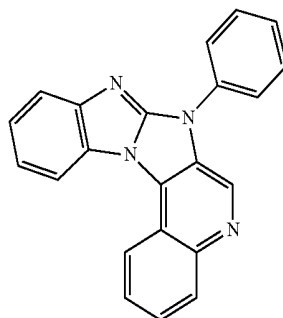
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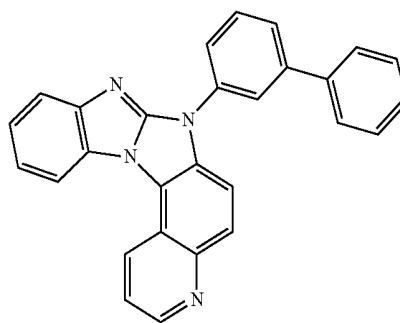
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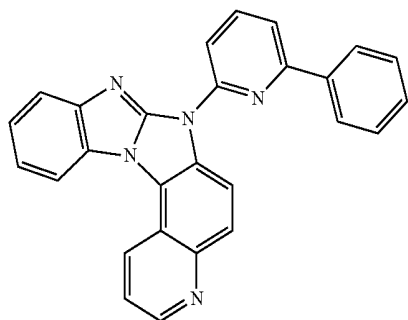


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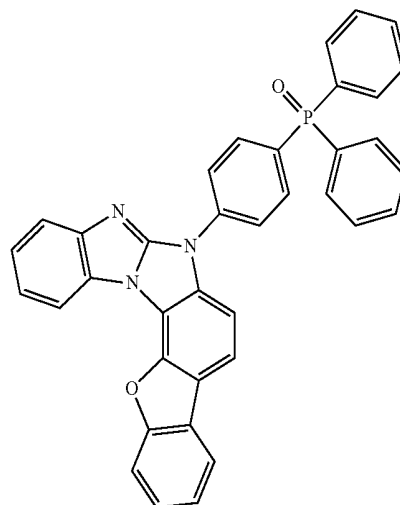
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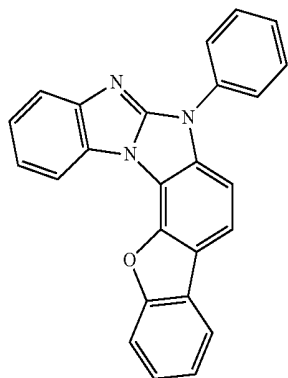
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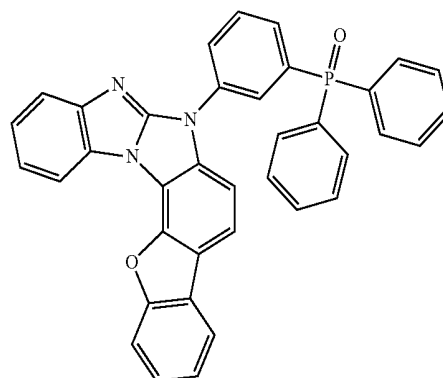


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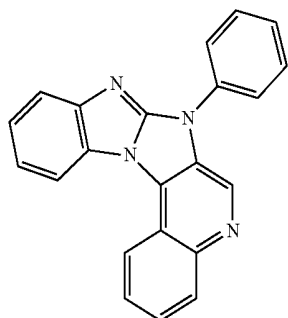
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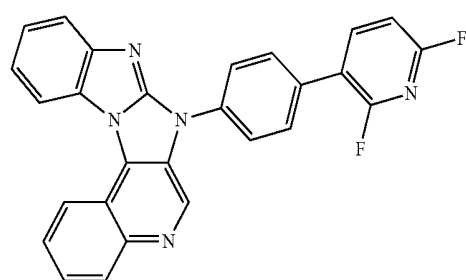
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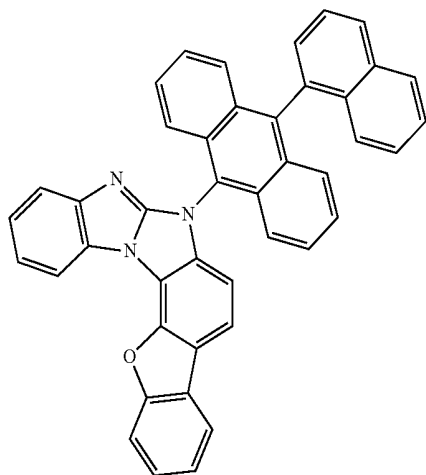
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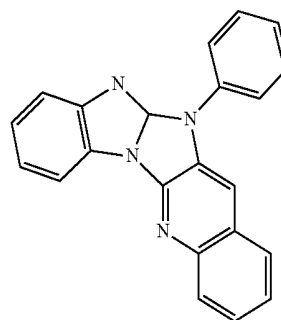
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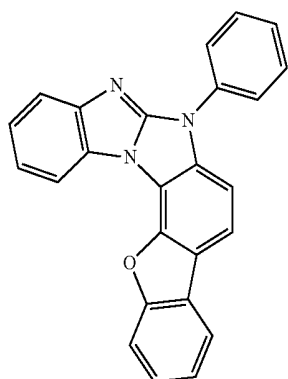
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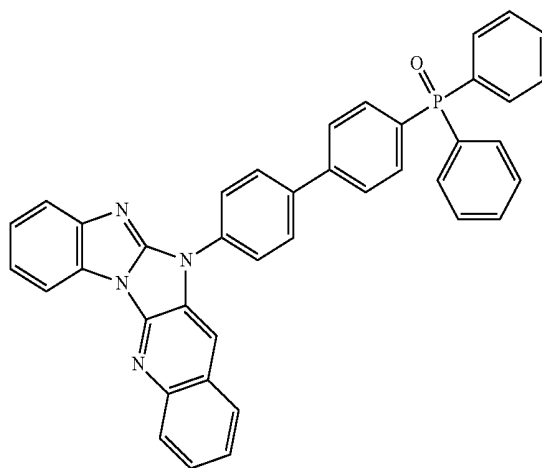


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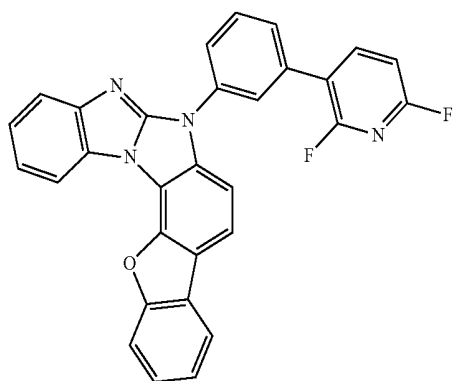


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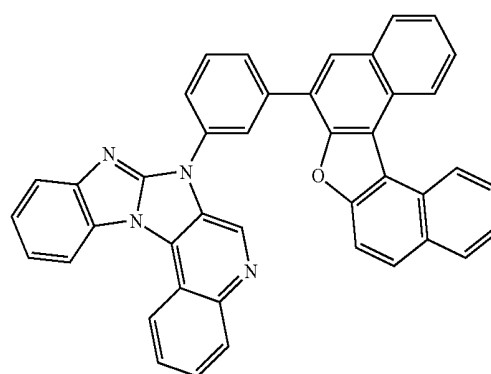
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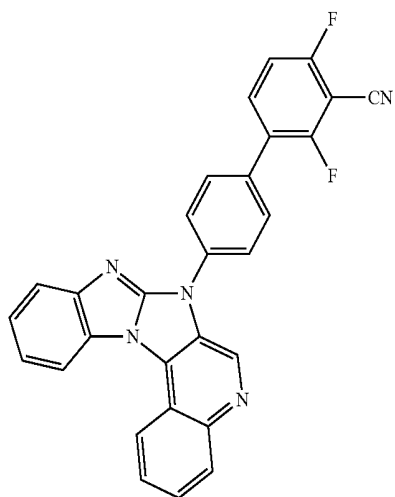
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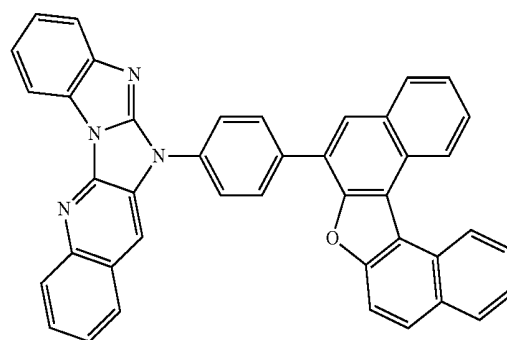
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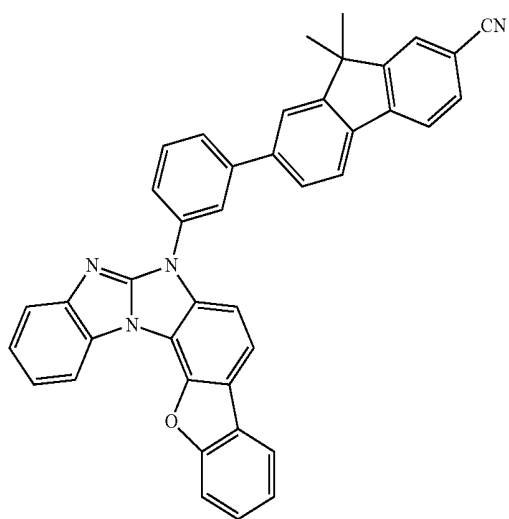
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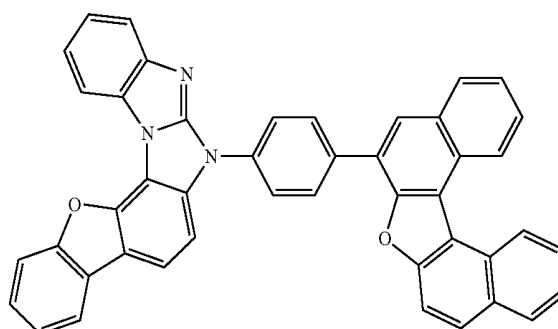
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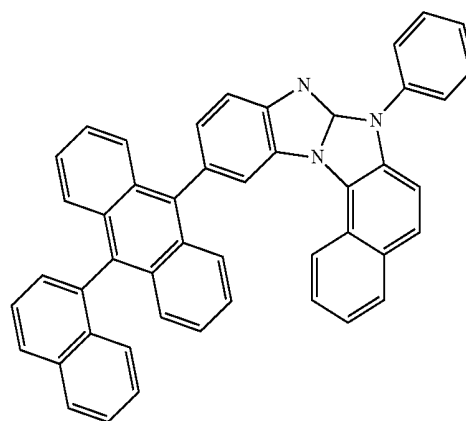


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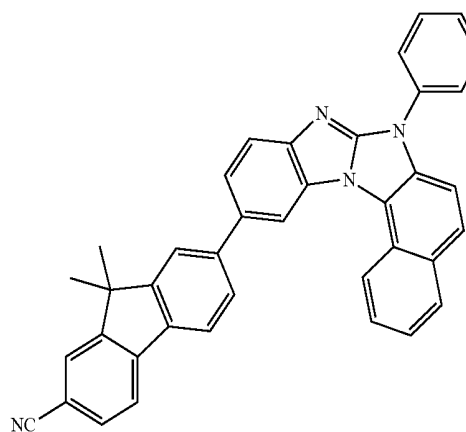
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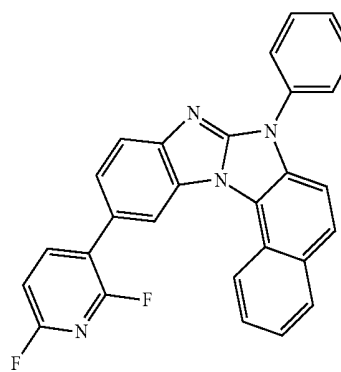
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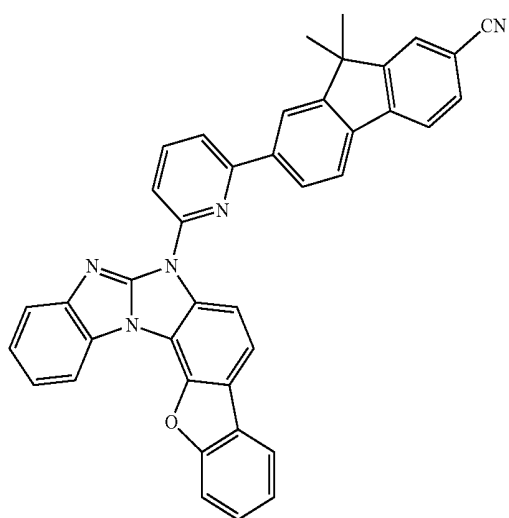
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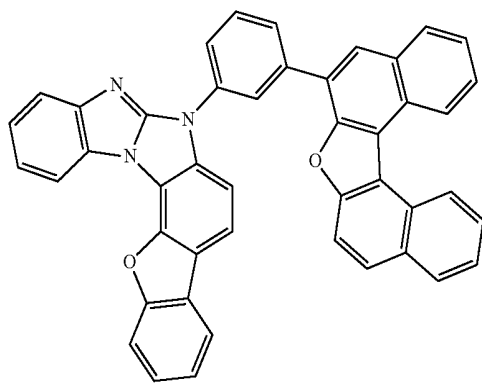
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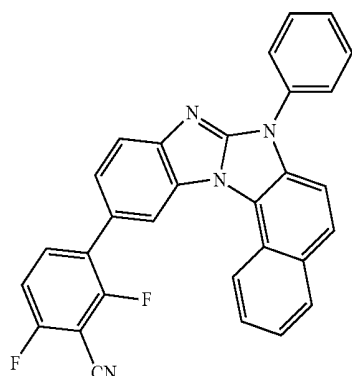
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[0169] The heterocyclic compound represented by Formula 1 may include a benzimidazole and has a heterocyclic core with five or more rings condensed with one another. For example, due to the inclusion of three or more heteroatoms and a condensed ring, the heterocyclic compound represented by Formula 1 may form a π -conjugated system. Thus, packing between molecules may be increased, and a glass transition temperature and a melting point may be increased. Also, a charge transport capability may also be increased. Therefore, an organic light-emitting device including the heterocyclic compound represented by Formula 1 may have high luminance and a long lifespan.

[0170] The compound represented by Formula 1 may have relatively high charge (hole or electron) transport capability. Accordingly, it may be possible to improve an exciton-forming ratio in an emission layer in the organic light-emitting device including the heterocyclic compound represented by Formula 1. Thus, the organic light-emitting device may have a low driving voltage and high efficiency.

[0171] The synthesis methods of the heterocyclic compound represented by Formula 1 may be recognizable by one of ordinary skill in the art by referring to Examples provided below.

[0172] At least one of the heterocyclic compounds represented by 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 of a hole transport region, an electron transport region, and an emission layer. In one or more embodiments, the heterocyclic compound represented by Formula 1 may be used as a material for a capping layer located outside a pair of electrodes of an organic light-emitting device.

[0173] According to one or more embodiments, an organic light-emitting device may include a first electrode; a second electrode facing the first electrode; and an organic layer that is disposed between the first electrode and the second electrode. The organic layer includes an emission layer. The organic layer may include at least one of the heterocyclic compounds represented by Formula 1.

[0174] The expression “(an organic layer) includes at least one of the heterocyclic compounds” 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 Formulae 1A to 1J.”

[0175] In one or more embodiments, the first electrode may be an anode, the second electrode may be a cathode, the organic layer may further include a hole transport region between the first electrode and the emission layer and an electron transport region between the emission layer and the second electrode. The hole transport region may include a hole injection layer, a hole transport layer, an emission auxiliary layer, an electron blocking layer, or any combination thereof. The electron transport region may include a buffer layer, a hole blocking layer, an electron control layer, an electron transport layer, an electron injection layer, or any combination thereof.

[0176] The organic light-emitting device may further include at least one selected from a first capping layer disposed in a pathway along which light generated in an emission layer proceeds toward outside through the first electrode and a second capping layer disposed in a pathway along which light generated in an emission layer proceeds toward outside through the second electrode. The at least one selected from the first capping layer and the second capping layer may include at least one of the heterocyclic compounds represented by Formula 1.

[0177] In one or more embodiments, the organic light-emitting device may have i) a stack structure including a first electrode, an organic layer, a second electrode, and a second capping layer which are sequentially stacked in this stated order, ii) a stack structure including a first capping layer, a first electrode, an organic layer, and a second electrode which are sequentially stacked in this stated order, or iii) a stack structure including a first capping layer, a first electrode, an organic layer, a second electrode, and a second capping layer which are sequentially stacked in this stated order. At least one selected from the first capping layer and the second capping layer may include the heterocyclic compound.

[0178] 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 in the organic light-emitting device. The organic layer may include other materials besides an organic material.

[0179] Description of FIG. 1

[0180] FIG. 1 illustrates a schematic view of an organic light-emitting device 10 according to an embodiment. The organic light-emitting device 10 may include a first electrode 110, an organic layer 150, and a second electrode 190.

[0181] 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 FIG. 1.

[0182] First electrode 110

[0183] In FIG. 1, a substrate may be additionally disposed under the first electrode 110 or above the second electrode 190. The substrate may be a substrate having excellent mechanical strength, thermal stability, transparency, surface

smoothness, ease of handling, and water-resistance. For example, the substrate may be glass substrate or a plastic substrate.

[0184] The first electrode 110 may be formed by depositing or sputtering a material for forming the first electrode 110 on the substrate. When the first electrode 110 is an anode, the material for forming the first electrode 110 may be selected from materials with a high work function to facilitate hole injection.

[0185] The first electrode 110 may be a reflective electrode, a semi-transmissive electrode, or a transmissive electrode. When the first electrode 110 is a transmissible electrode, a material for forming the first electrode 110 may be selected from indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO_2), zinc oxide (ZnO), and any combinations thereof, as examples. 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, as examples.

[0186] 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, as an example.

[0187] Organic layer 150

[0188] The organic layer 150 may be disposed on the first electrode 110. The organic layer 150 may include an emission layer.

[0189] 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.

[0190] Hole transport region in organic layer 150

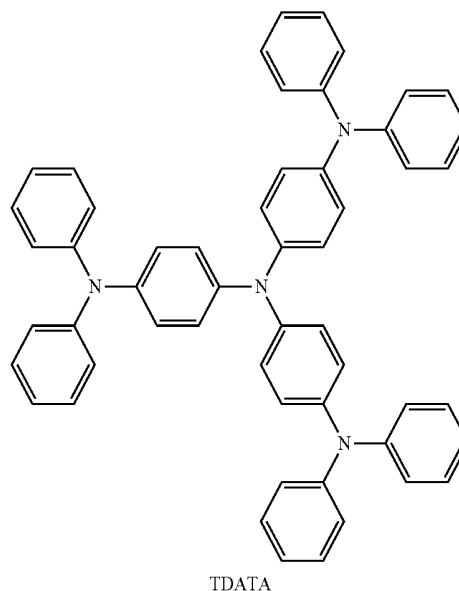
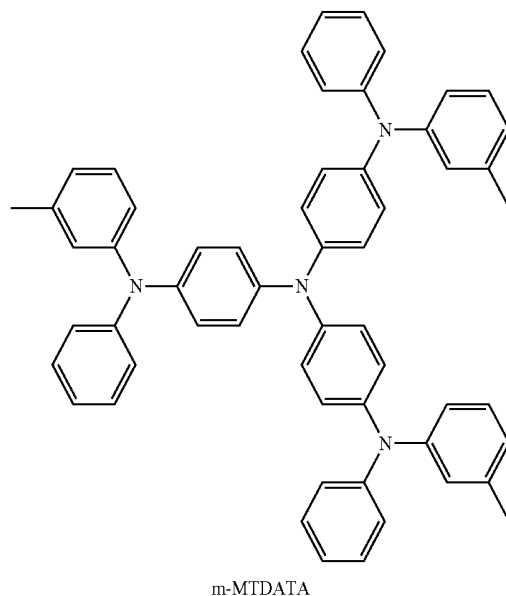
[0191] The hole transport region may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

[0192] The hole transport region may include at least one layer selected from a hole injection layer, a hole transport layer, an emission auxiliary layer, and an electron blocking layer.

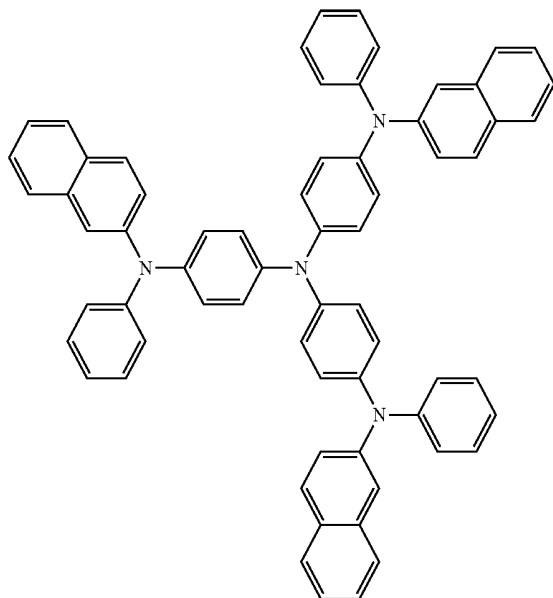
[0193] For example, the hole transport region may have a single-layered structure including a single layer including a plurality of different materials, or a multi-layered structure having a hole injection layer/hole transport layer structure, a hole injection layer/hole transport layer/emission auxiliary 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 the stated order.

[0194] The hole transport region may include at least one selected from m-MTDATA, TDATA, 2-TNATA, NPB

(NPD), β -NPB, TPD, Spiro-TPD, Spiro—NPB, methylated-NPB, TAPC, HMTPD, 4,4',4''-tris(N-carbazolyl)triphenylamine (TCTA), polyaniline/dodecylbenzenesulfonic acid (Pani/DBSA), PEDOT/PSS (poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate)), polyaniline/camphor sulfonic acid (Pani/CSA), polyaniline/poly(4-styrenesulfonate) (Pani/PSS), a compound represented by Formula 201, and a compound represented by Formula 202:

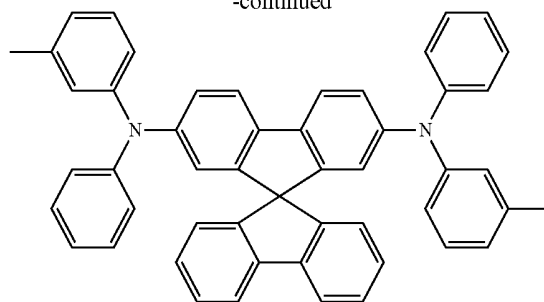


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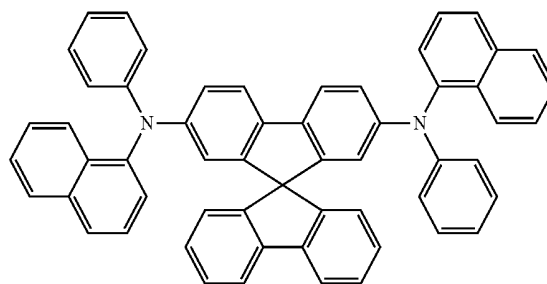


2-TNATA

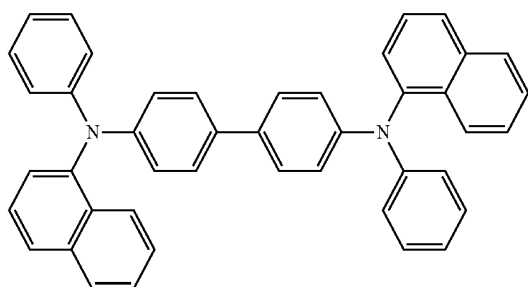
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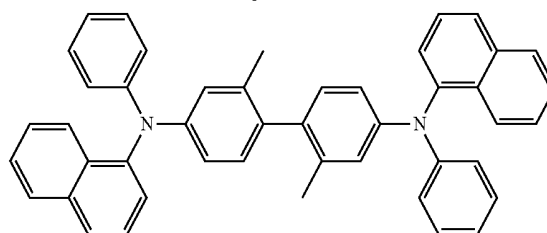
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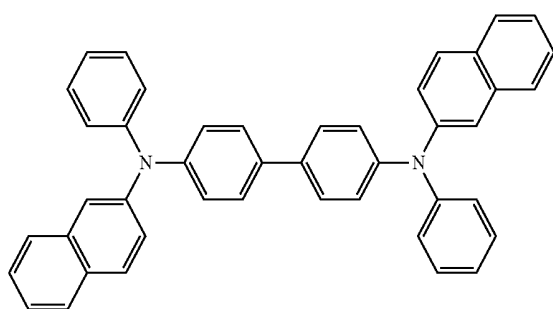
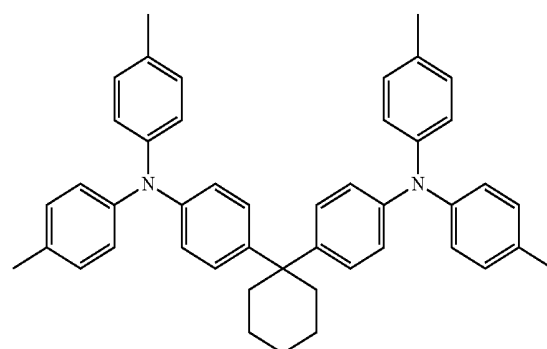
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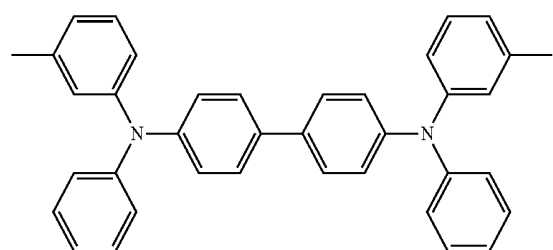
NPB



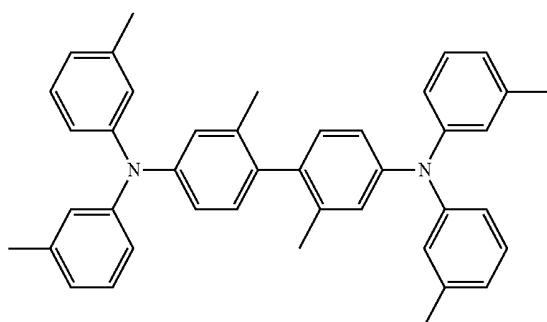
methylated NPB

 β -NPB

TAPC



TPD



HMTDP

[10205] a phenylene group, a pentalenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an indacenylene group, an acenaphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenalenylenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylenylene group, a picenylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylenylene group, a pentacenylenylene group, a rubicenylenylene group, a coronenylenylene group, an ovalenylenylene 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, 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 C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C₁-C₁₀ alkyl group, a phenyl group substituted with —F, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a 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 benzofuranlyl group, a benzothiophe-

nyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, and $-\text{N}(\text{Q}_{31})(\text{Q}_{32})$,

[0206] wherein Q_{31} to Q_{33} may each independently be selected from a $\text{C}_1\text{-C}_{10}$ alkyl group, a $\text{C}_1\text{-C}_{10}$ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0207] In one or more embodiments, xa1 to xa4 may each independently be an integer selected from 0, 1, and 2.

[0208] In one or more embodiments, xa5 may be 1, 2, 3, or 4.

[0209] 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 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; and

[0210] a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a 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, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a $\text{C}_1\text{-C}_{20}$ alkyl group, a $\text{C}_1\text{-C}_{20}$ alkoxy group, a 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 $\text{C}_1\text{-C}_{10}$ alkyl group, a phenyl group substituted with $-\text{F}$, 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, a pyridinyl group, $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, and $-\text{N}(\text{Q}_{31})(\text{Q}_{32})$,

[0211] wherein Q_{31} to Q_{33} are the same as described above.

[0212] In one or more embodiments, at least one selected from R_{201} to R_{203} in Formula 201 may each independently be selected from:

[0213] a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

[0214] a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a $\text{C}_1\text{-C}_{20}$ alkyl group, a $\text{C}_1\text{-C}_{20}$ 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 $\text{C}_1\text{-C}_{10}$ alkyl group, a phenyl group substituted with $-\text{F}$, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, as examples.

[0215] 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.

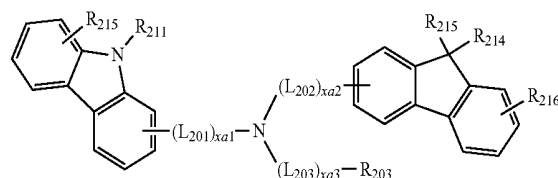
[0216] In one or more embodiments, at least one selected from R_{201} to R_{204} in Formula 202 may be selected from:

[0217] a carbazolyl group; and

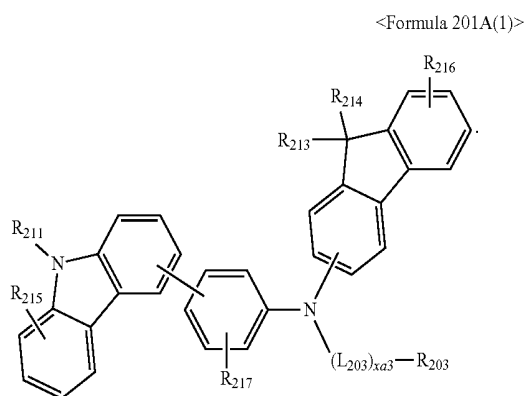
[0218] a carbazolyl group, substituted with at least one selected from deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a $\text{C}_1\text{-C}_{20}$ alkyl group, a $\text{C}_1\text{-C}_{20}$ 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 $\text{C}_1\text{-C}_{10}$ alkyl group, a phenyl group substituted with $-\text{F}$, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, as examples.

[0219] The compound represented by Formula 201 may be represented by Formula 201A:

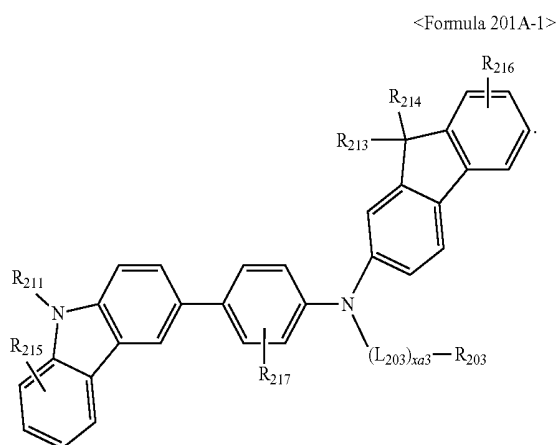
<Formula 201A>



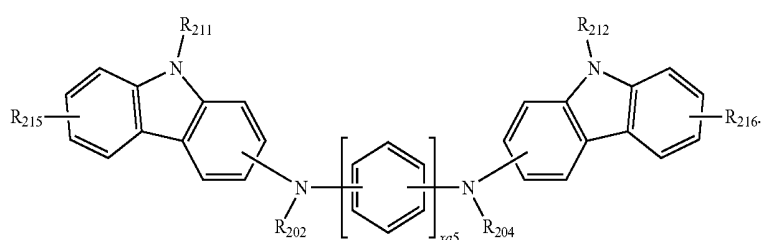
[0220] In one or more embodiments, the compound represented by Formula 201 may be represented by Formula 201A(1) below, as an example:



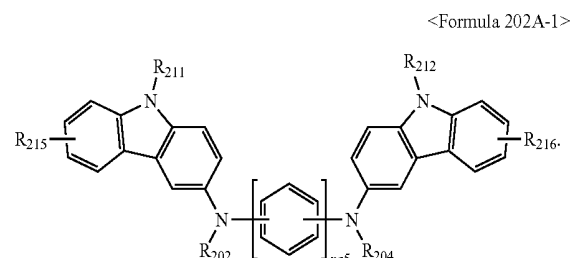
[0221] In one or more embodiments, the compound represented by Formula 201 may be represented by Formula 201A-1 below, as an example:



[0222] In one or more embodiments, the compound represented by Formula 202 may be represented by Formula 202A:



[0223] In one or more embodiments, the compound represented by Formula 202 may be represented by Formula 202A-1:



[0224] In Formulae 201A, 201A(1), 201A-1, 202A, and 202A-1,

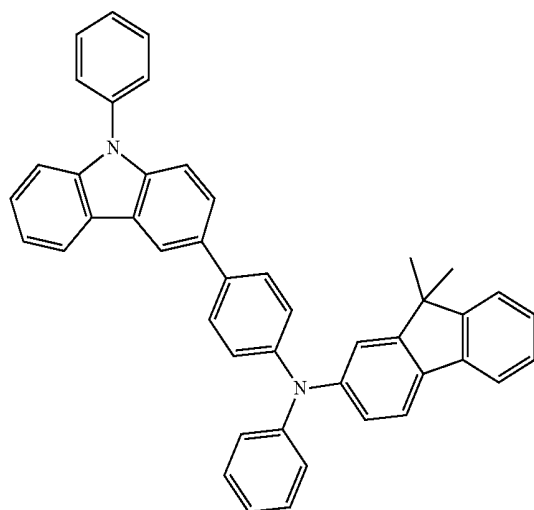
[0225] L_{201} to L_{203} , $xa1$ to $xa3$, $xa5$, and R_{202} to R_{204} are the same as described above, and

[0226] R_{211} and R_{212} may be the same as described in connection with R_{203} .

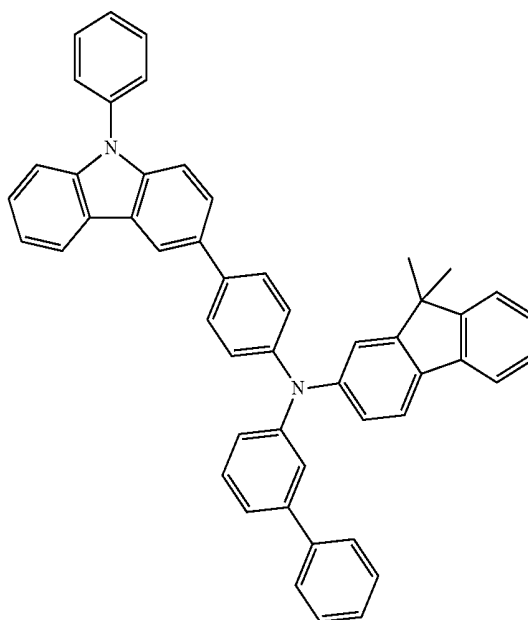
[0227] R_{213} to R_{217} may each independently be selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl 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.

[0228] The hole transport region may include at least one compound selected from Compounds HT1 to HT39, as examples:

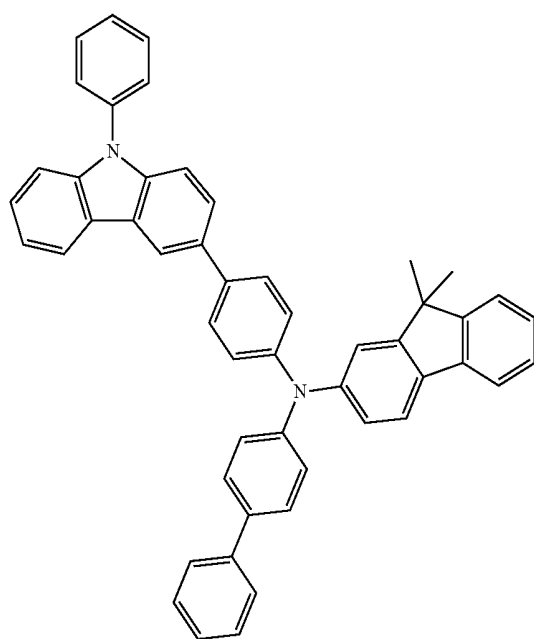
HT1



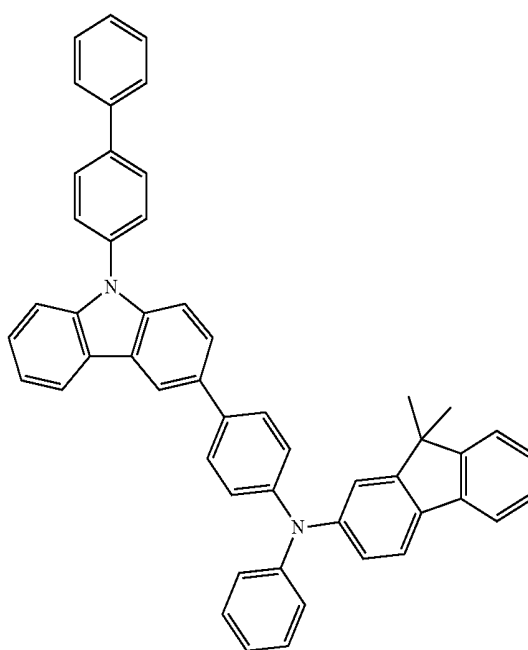
HT2



HT3

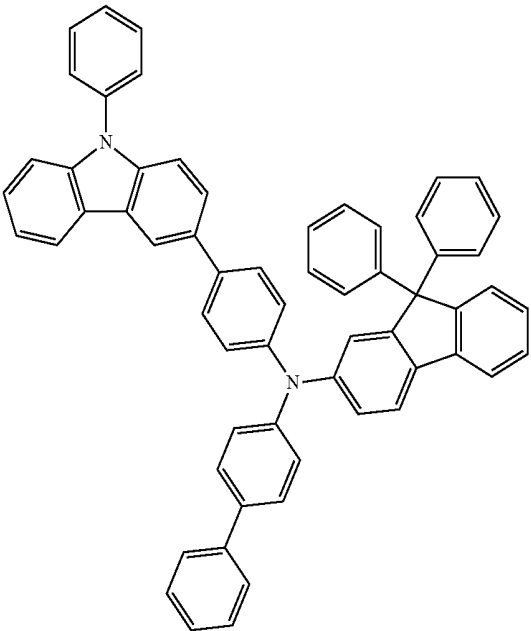
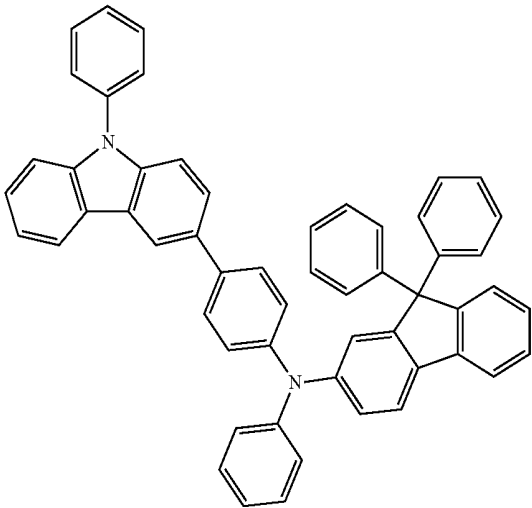


HT4



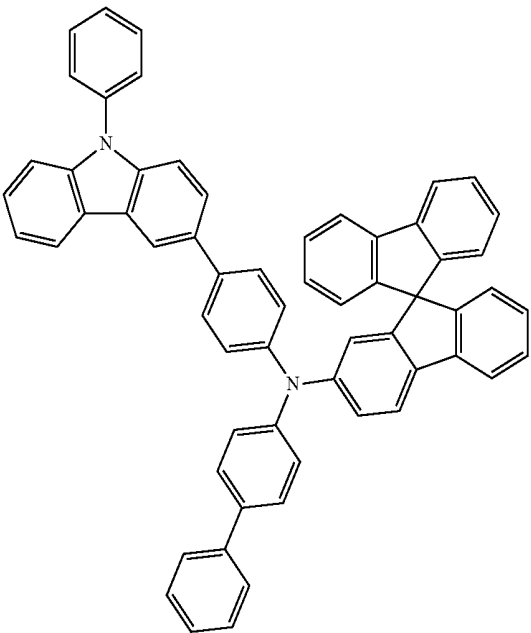
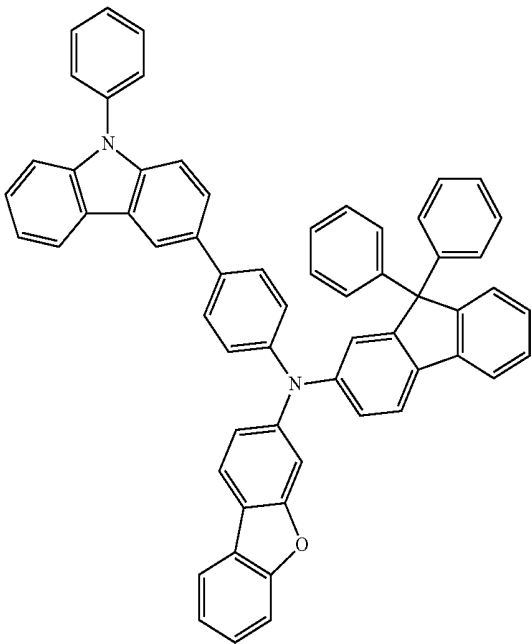
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HT5

HT6



HT7

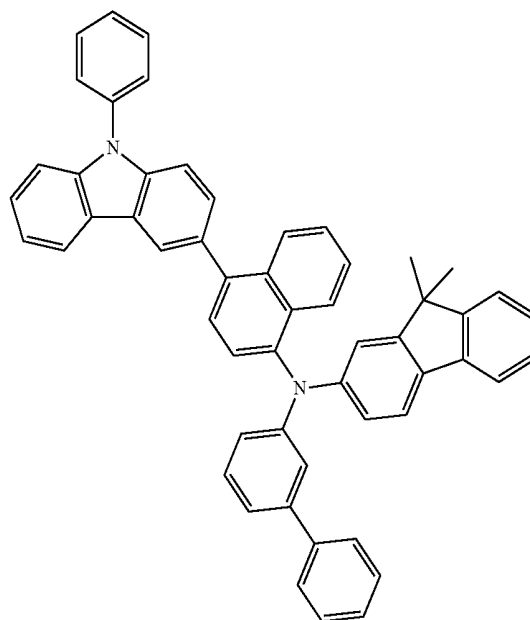
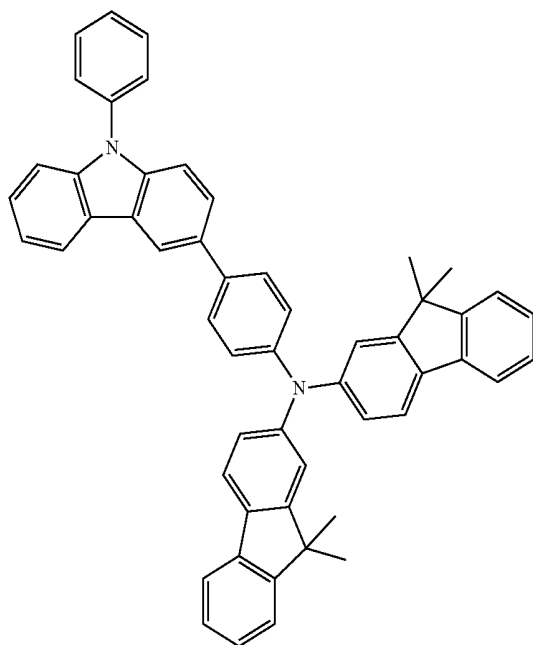
HT8



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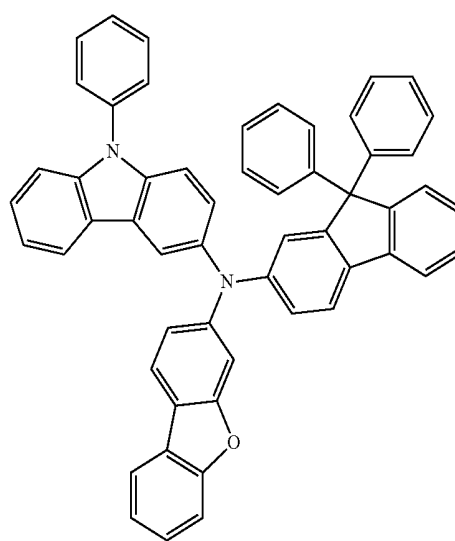
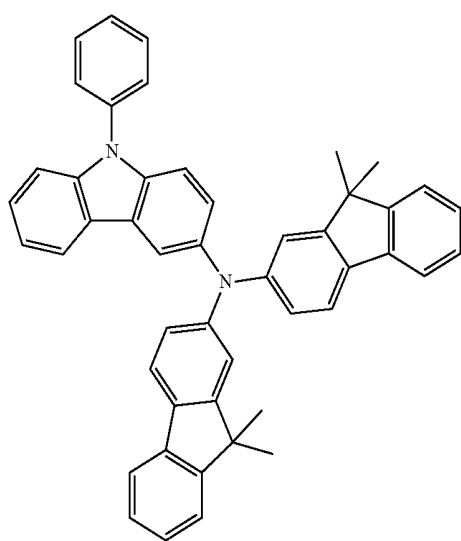
HT9

HT10

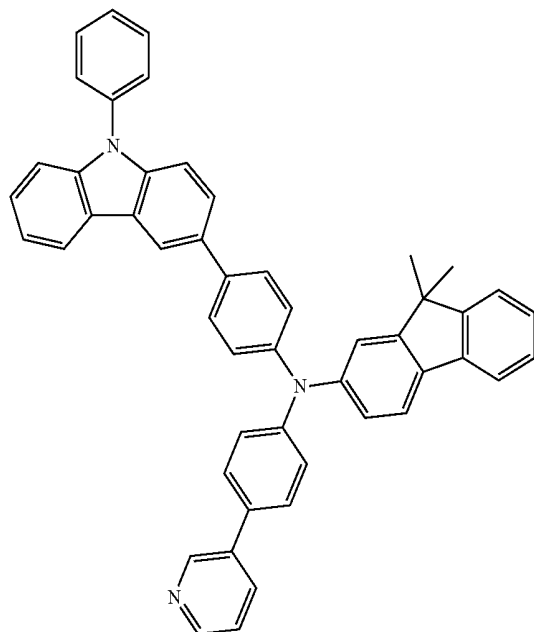


HT11

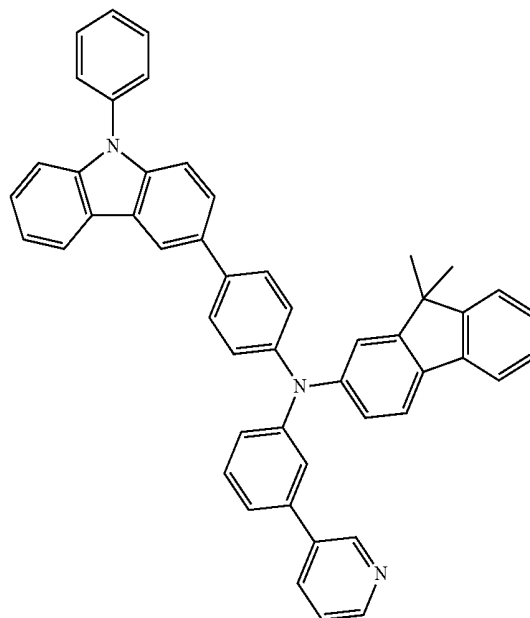
HT12



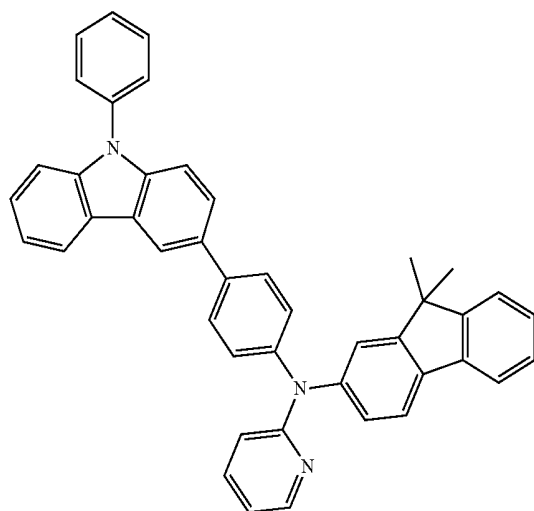
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HT13



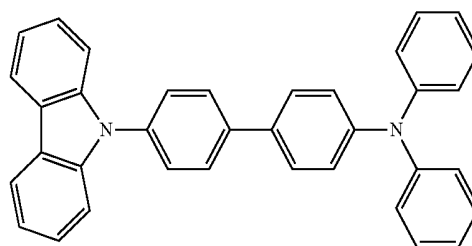
HT14



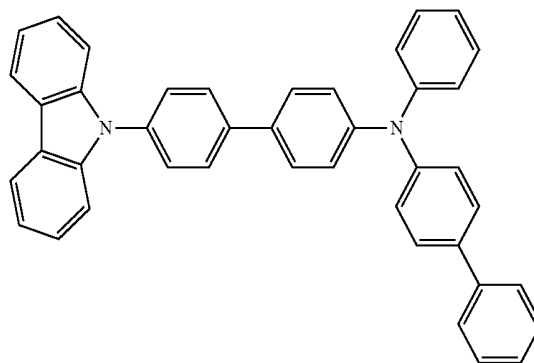
HT15



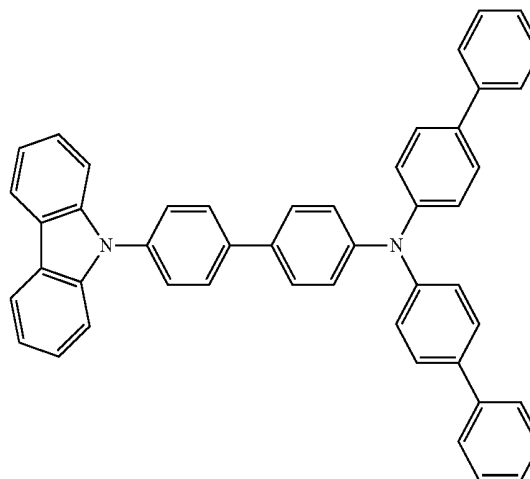
HT16



HT17



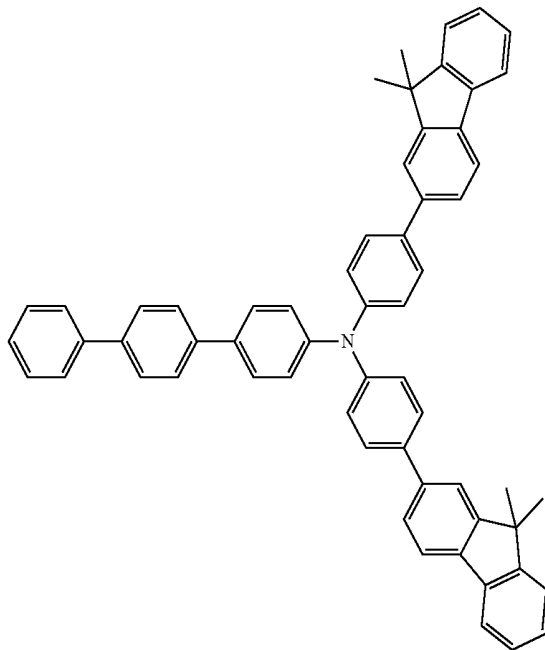
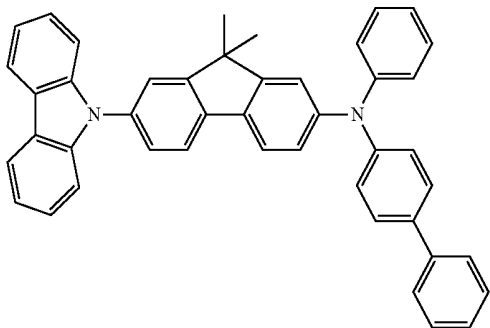
HT18



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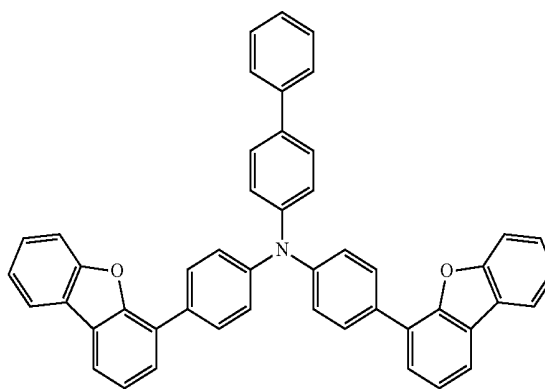
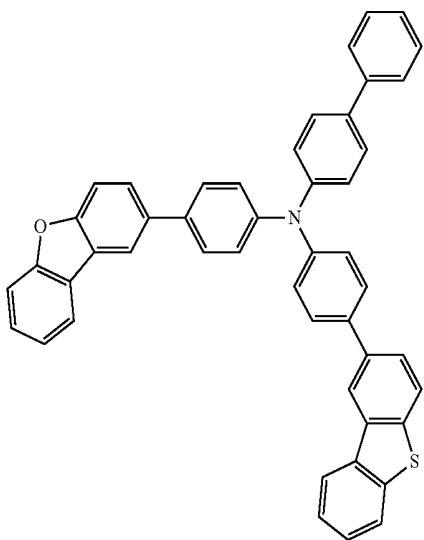
HT19

HT20



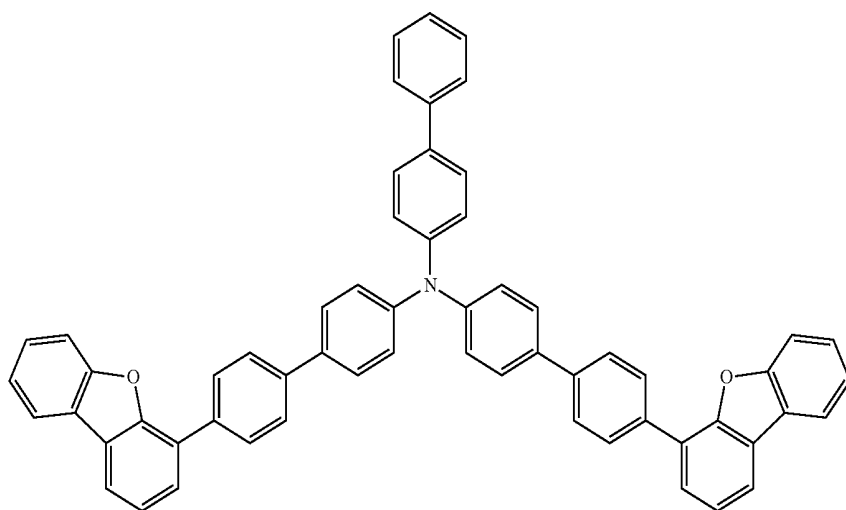
HT21

HT22

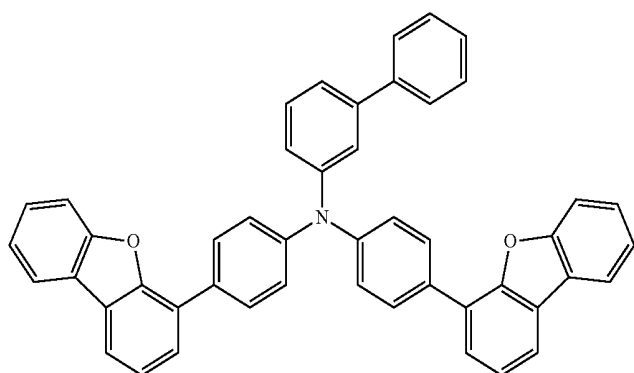


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HT23

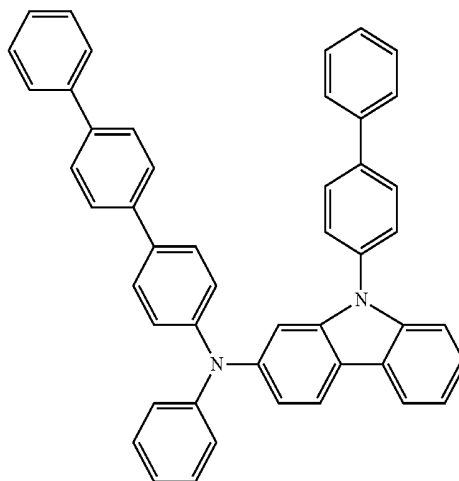
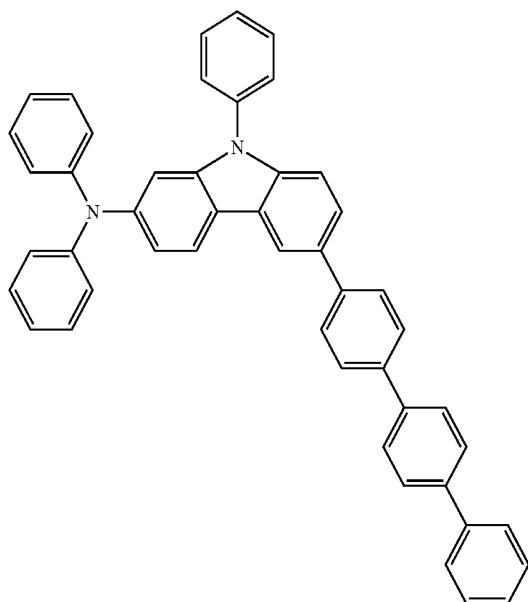


HT24



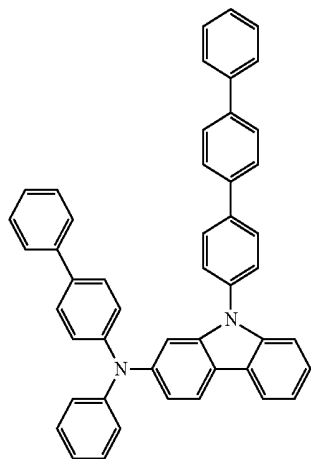
HT25

HT26

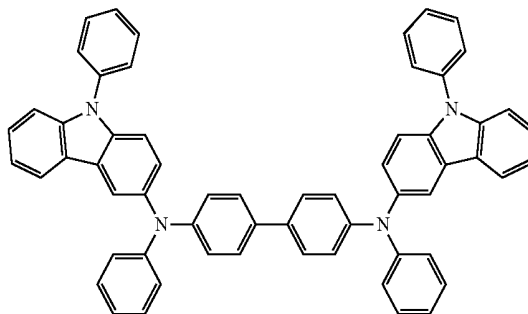


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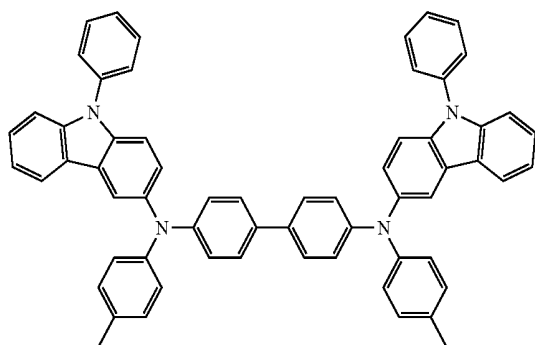
HT27



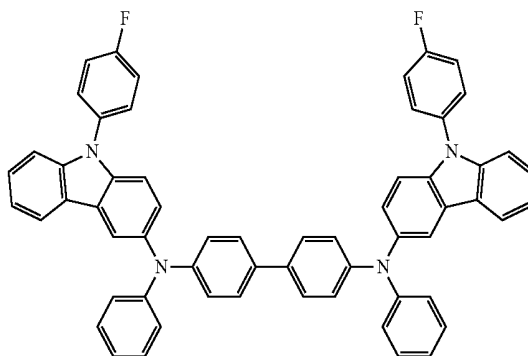
HT28



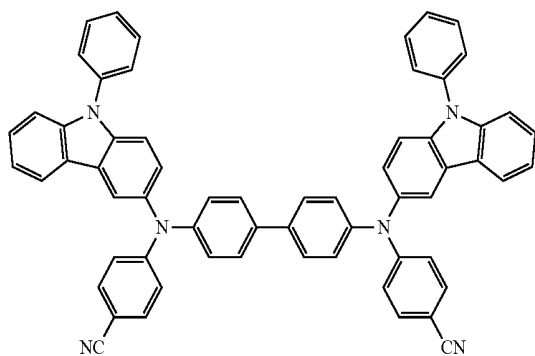
HT29



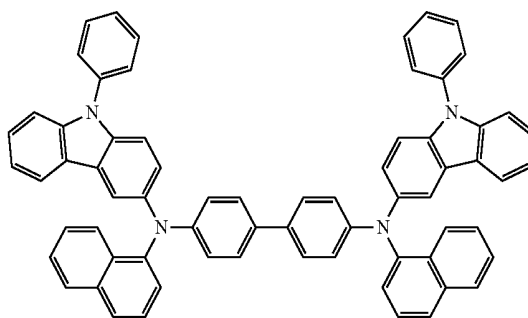
HT30



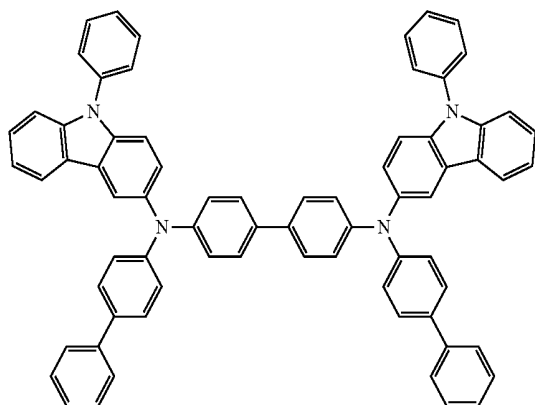
HT31



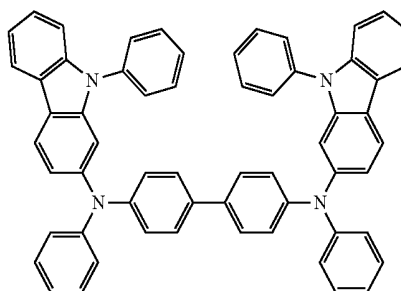
HT32

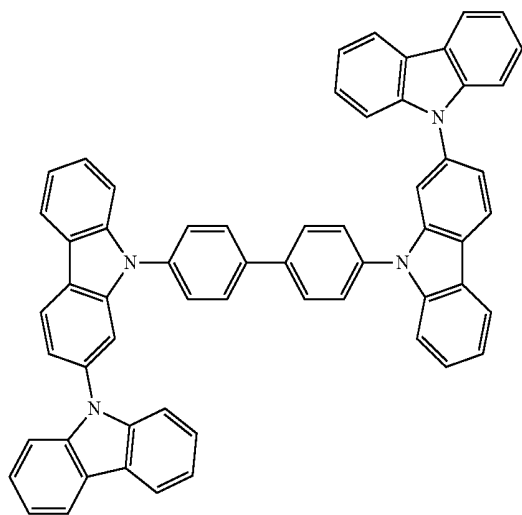


HT33

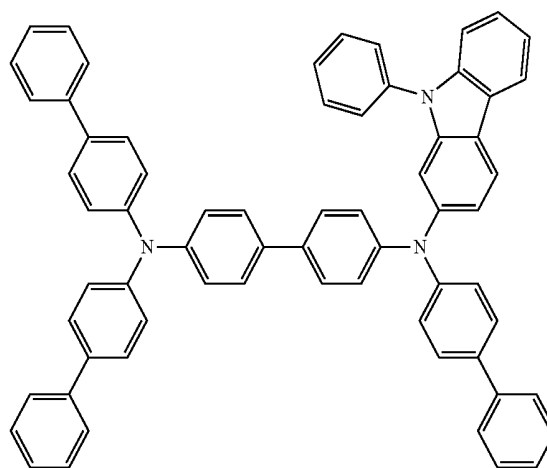


HT34

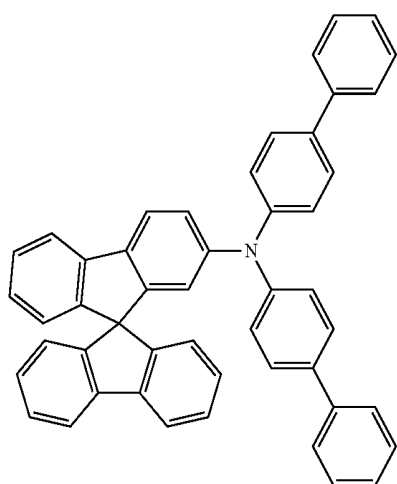


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HT35

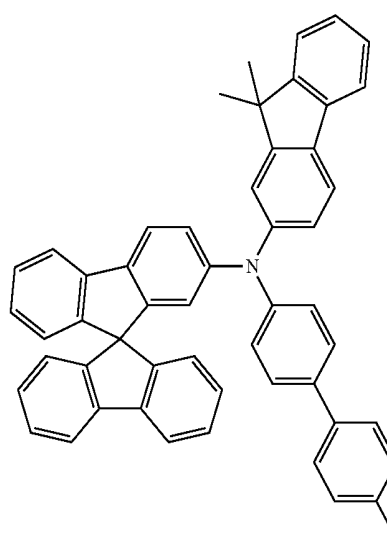
HT36



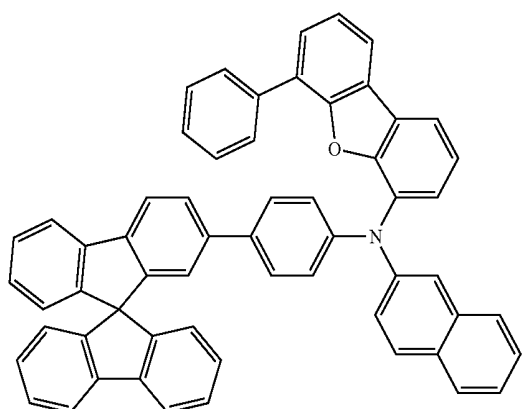
HT37



HT38



HT39



[0229] A thickness of the hole transport region may be in a range of about 100 Å to about 10,000 Å, or, for example, about 100 Å to about 1,000 Å. When the hole transport region includes at least one of a hole injection layer and a hole transport layer, the thickness of the hole injection layer may be in a range of about 100 Å to about 9,000 Å, or, for example, about 100 Å to about 1,000 Å, and the thickness

of the hole transport layer may be in a range of about 50 Å to about 2,000 Å, or, 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, satisfactory hole transporting characteristics may be obtained without a substantial increase in driving voltage.

[0230] The emission auxiliary layer may increase light-emission efficiency by compensating for an optical resonance distance according to the wavelength of light emitted by an emission layer.

[0231] 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.

[0232] p-dopant

[0233] 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.

[0234] The charge-generation material may be, for example, a p-dopant.

[0235] In one or more embodiments, a lowest unoccupied molecular orbital (LUMO) level of the p-dopant may be -3.5 eV or less.

[0236] The p-dopant may include at least one selected from a quinone derivative, a metal oxide, and a cyano group-containing compound, as examples.

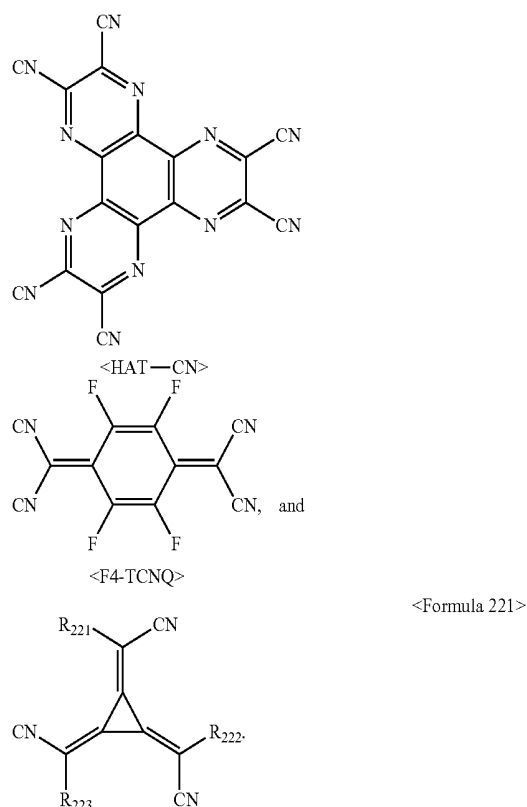
[0237] For example, the p-dopant may include at least one selected from:

[0238] a quinone derivative, such as tetracyanoquinodimethane (TCNQ) or 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F4-TCNQ);

[0239] a metal oxide, such as tungsten oxide or molybdenum oxide;

[0240] 1,4,5,8,9,11-hexaazatriphenylene-hexacarbonitrile (HAT-CN); and

[0241] a compound represented by Formula 221, as examples:



[0242] In Formula 221,

[0243] R₂₂₁ to R₂₂₃ may each independently be selected from a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, provided that at least one selected from R₂₂₁ to R₂₂₃ has at least one substituent selected from a cyano group, —F, —Cl, —Br, —I, a C₁-C₂₀ alkyl group substituted with —F, a C₁-C₂₀ alkyl group substituted with —Cl, a C₁-C₂₀ alkyl group substituted with —Br, and a C₁-C₂₀ alkyl group substituted with —I.

[0244] Emission layer in organic layer 150

[0245] 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 emission material, a green-light emission material, and a blue-light emission material, in which the two or more materials are mixed with each other in a single layer to emit white light.

[0246] 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.

[0247] An amount of the dopant in the emission layer may be, for example, in a range of about 0.01 to about 15 parts by weight based on 100 parts by weight of the host.

[0248] A thickness of the emission layer may be in a range of about 100 Å to about 1,000 Å, or, 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.

[0249] Host in emission layer

[0250] In one or more embodiments, the host may include a compound represented by Formula 301 below:



[0251] In Formula 301,

[0252] Ar₃₀₁ may be a substituted or unsubstituted C₅-C₆₀ carbocyclic group or a substituted or unsubstituted C₁-C₆₀ heterocyclic group,

[0253] xb11 may be 1, 2, or 3,

[0254] L₃₀₁ may be selected from a substituted or unsubstituted C₃-C₁₀ cycloalkylene group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkylene group, a substituted or unsubstituted C₃-C₁₀ cycloalkenylene group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenylene group, a substituted or unsubstituted C₆-C₆₀ arylene group, a substituted or unsubstituted C₁-C₆₀ heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group;

[0255] xb1 may be an integer selected from 0 to 5,

[0256] R₃₀₁ may be selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group,

an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted 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, $-\text{Si}(\text{Q}_{301})(\text{Q}_{302})(\text{Q}_{303})$, $-\text{N}(\text{Q}_{301})$

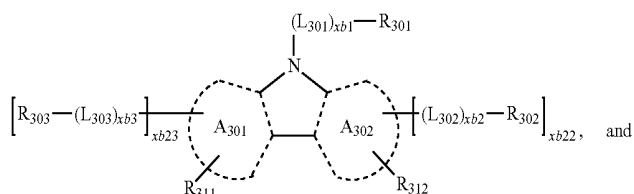
selected from deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$, $-\text{N}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{B}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{C}(=\text{O})(\text{Q}_{31})$, $-\text{S}(=\text{O})_2(\text{Q}_{31})$, and $-\text{P}(=\text{O})(\text{Q}_{31})(\text{Q}_{32})$.

[0262] wherein Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, as examples.

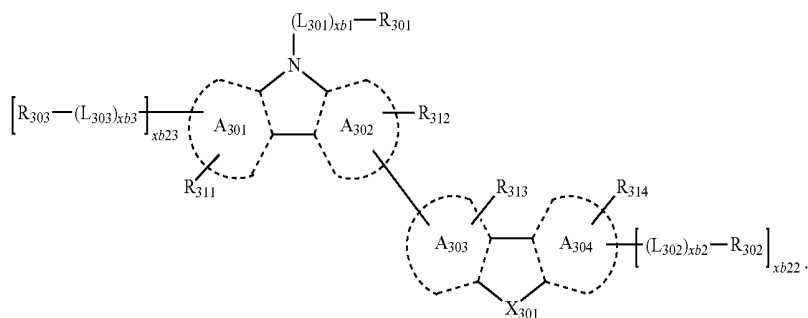
[0263] When xb11 in Formula 301 is two or more, two or more Ar_{301} (s) may be linked via a single bond.

[0264] 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>



(Q_{302}) , $-\text{B}(\text{Q}_{301})(\text{Q}_{302})$, $-\text{C}(=\text{O})(\text{Q}_{301})$, $-\text{S}(=\text{O})_2(\text{Q}_{301})$, and $-\text{P}(=\text{O})(\text{Q}_{301})(\text{Q}_{302})$, and

[0257] xb21 may be an integer selected from 1 to 5,

[0258] wherein 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, as examples.

[0259] In one or more embodiments, Ar_{301} in Formula 301 may be selected from:

[0260] a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group and a dibenzothiophene group; and

[0261] a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, and a dibenzothiophene group, each substituted with at least one

[0265] In Formulae 301-1 to 301-2,

[0266] A_{301} to A_{304} may each independently be selected from a benzene, a naphthalene, a phenanthrene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a pyridine, a pyrimidine, an indene, a fluorene, a spiro-bifluorene, a benzofluorene, a dibenzofluorene, an indole, a carbazole, benzocarbazole, dibenzocarbazole, a furan, a benzofuran, a dibenzofuran, a naphthofuran, a benzonaphthofuran, a dinaphthofuran, a thiophene, a benzothiophene, a dibenzothiophene, a naphthothiophene, a benzonaphthothiophene, and dinaphthothiophene,

[0267] X_{301} may be O, S, or $\text{N}-[(\text{L}_{304})_{\text{xb4}}-\text{R}_{304}]$,

[0268] R_{311} to R_{314} may each independently be selected from hydrogen, deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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 $-\text{P}(=\text{O})(\text{Q}_{31})(\text{Q}_{32})$,

[0269] xb22 and xb23 may each independently be 0, 1, or 2,

[0270] L_{301} , xb1 , R_{301} , and Q_{31} to Q_{33} are the same as described above,

[0271] L_{302} to L_{304} are each independently the same as described in connection with L_{301} ,

[0272] $xb2$ to $xb4$ are each independently the same as described in connection with $xb1$, and

[0273] R_{302} to R_{304} are each independently the same as described in connection with R_{301} .

[0274] For example, L_{301} to L_{304} in Formulae 301, 301-1, and 301-2 may each independently be selected from:

[0275] 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 hexacenylene group, a pentacenylene 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 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 imidazopyrimidinylenylene group, and an azacarbazolylenylene group; and

[0276] 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 hexacenylene group, a pentacenylene 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 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 imidazopyrimidinylenylene group, and an azacarbazolylenylene 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 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 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 azacarbazoyl 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}),

[0277] wherein Q_{31} to Q_{33} may be the same as described above.

[0278] In one or more embodiments, R_{301} to R_{304} in Formulae 301, 301-1, and 301-2 may each independently be selected from:

[0279] 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 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 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 azacarbazoyl group; and

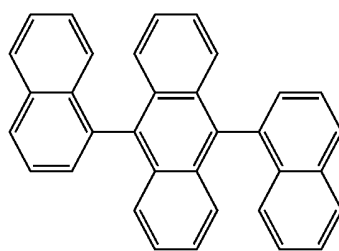
[0280] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a

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, 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 quinoxalyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a 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 quinoxalyl 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(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂).

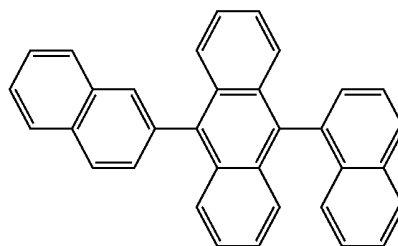
[0281] wherein Q₃₁ to Q₃₃ may be the same as described above.

[0282] 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), an Mg complex, and a Zn complex.

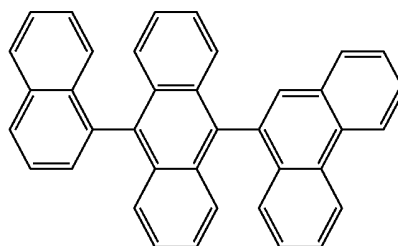
[0283] The host may include at least one selected from 9,10-di(2-naphthyl)anthracene (ADN), 2-methyl-9,10-bis(naphthalen-2-yl)anthracene (MADN), 9,10-di(2-naphthyl)-2-t-butyl-anthracene (TBADN), a 4,4'-bis(N-carbazolyl)-1,1'-biphenyl (CBP), 1,3-di-9-carbazolylbenzene (mCP), 1,3,5-tri(carbazol-9-yl)benzene (TCP), and Compounds H1 to H55, as examples:



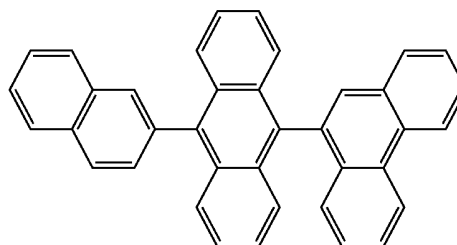
H1



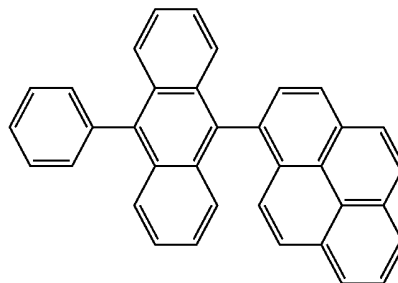
H2



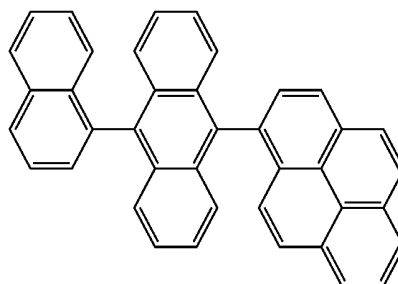
H3



H4

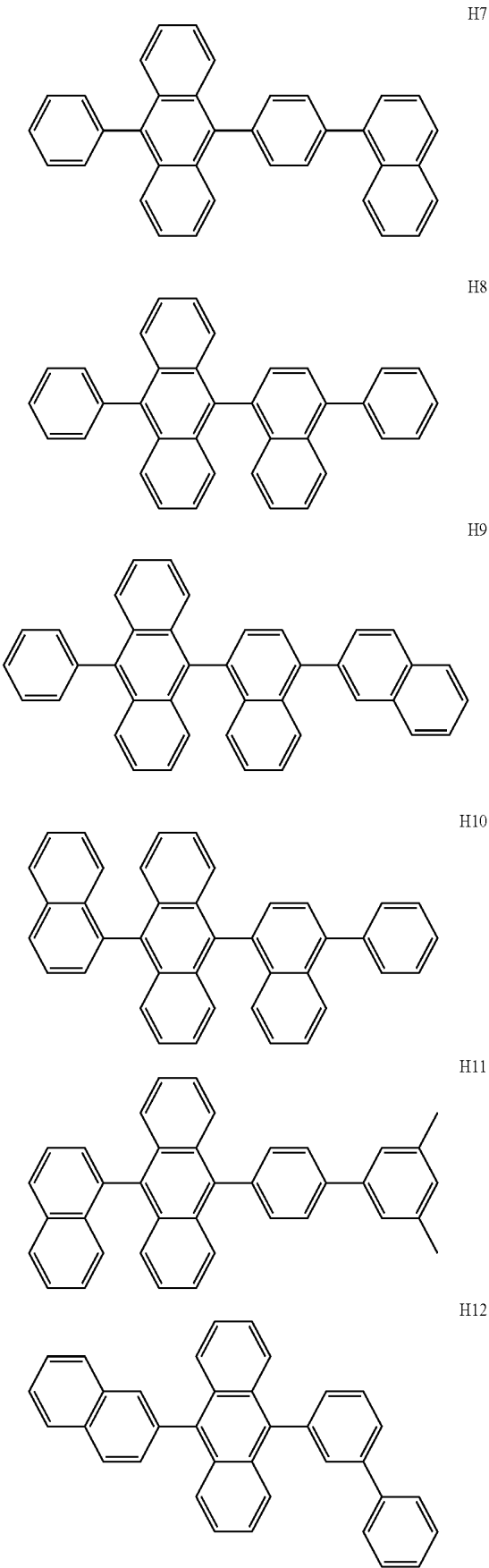


H5

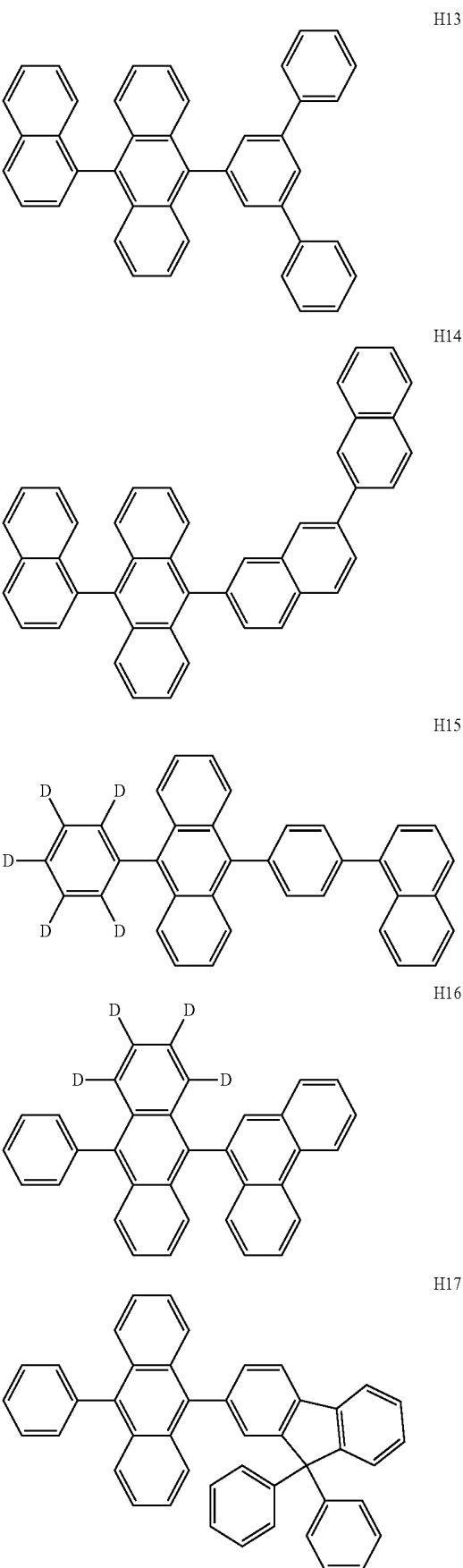


H6

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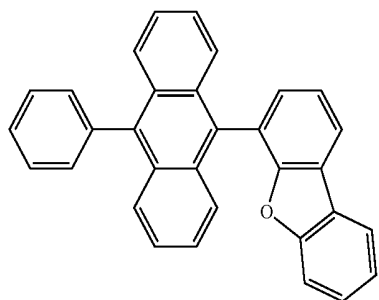


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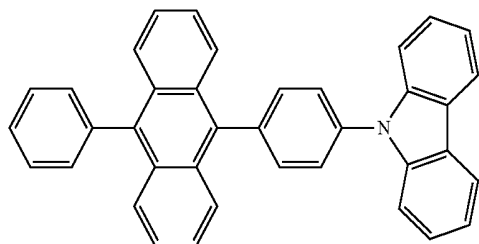


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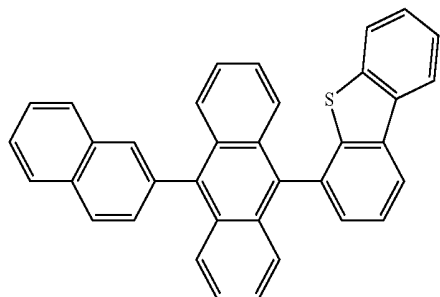
H18



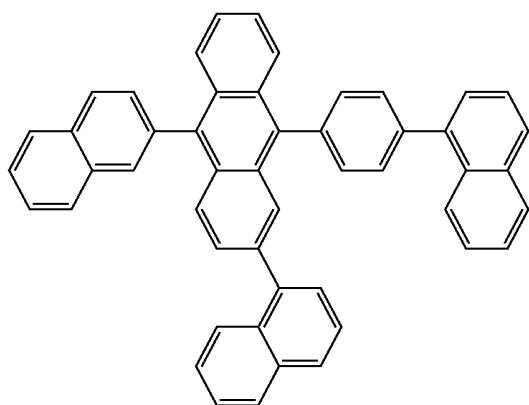
H19



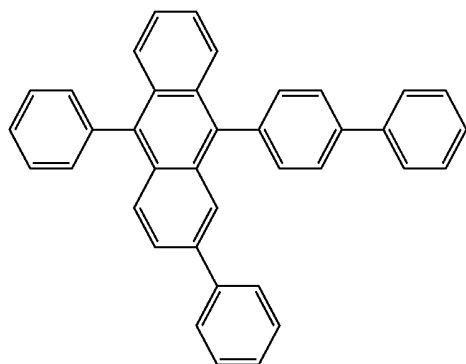
H20



H21

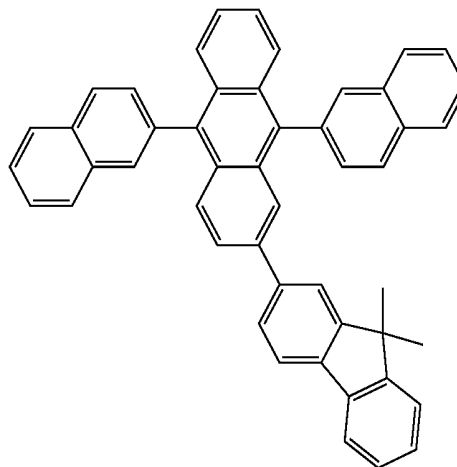


H22

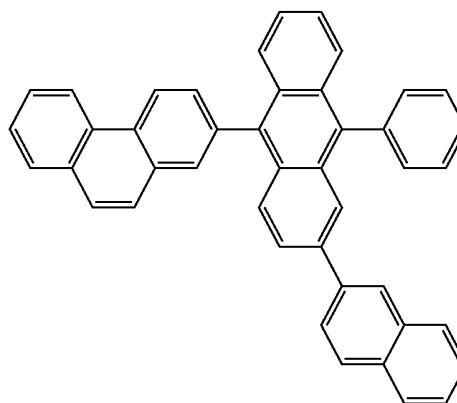


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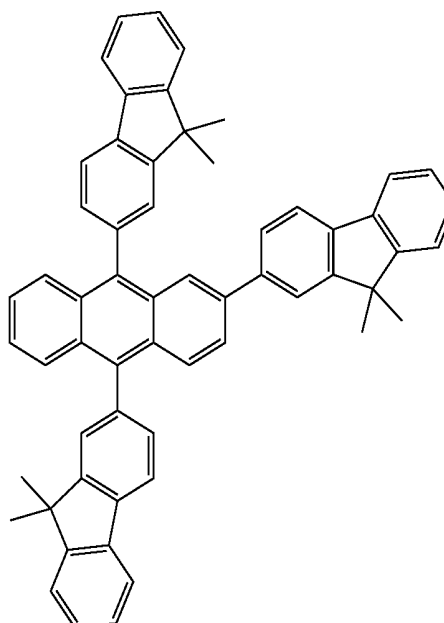
H23



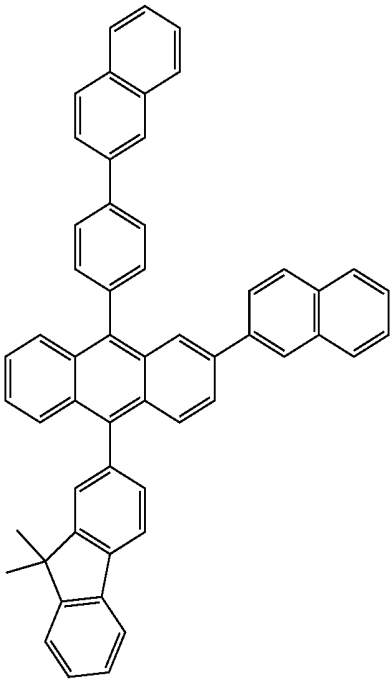
H24



H25

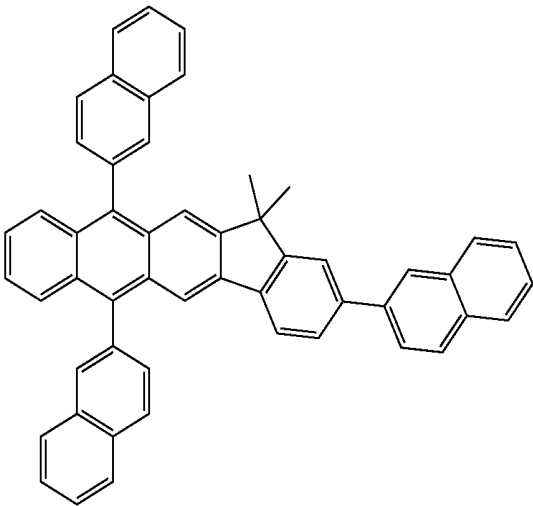


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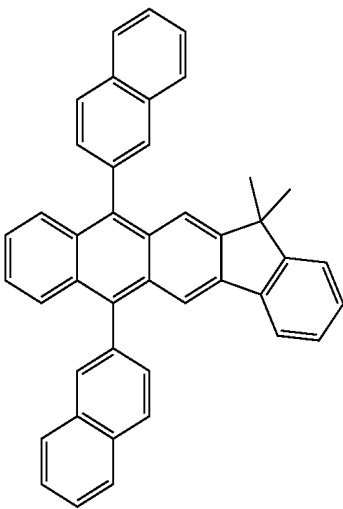


H26

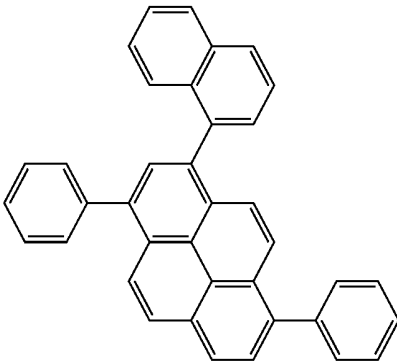
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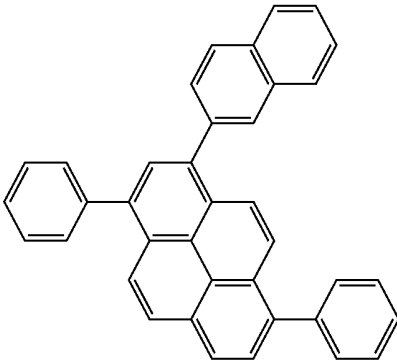
H28



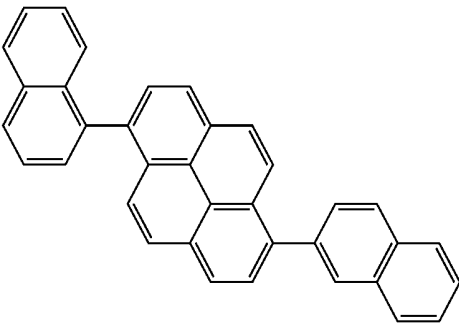
H27



H29



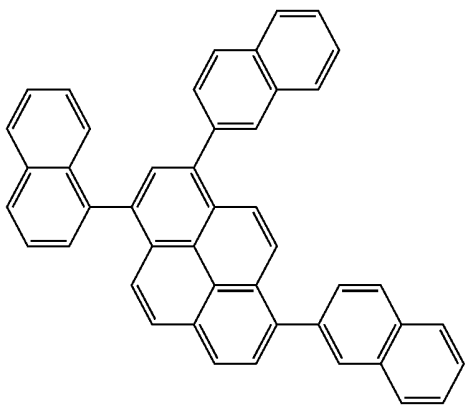
H30



H31

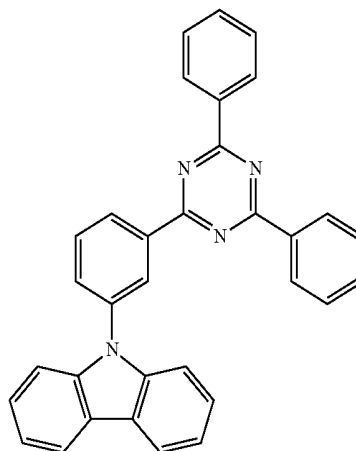
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H32

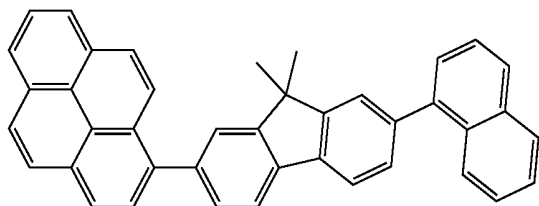


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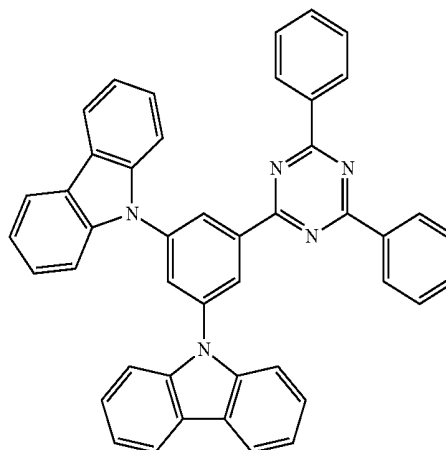
H36



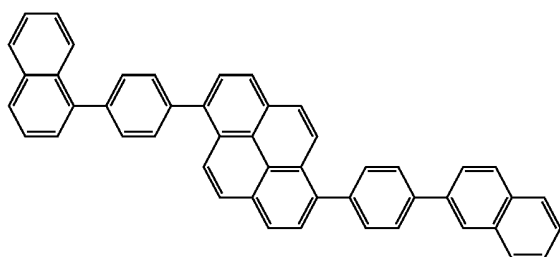
H33



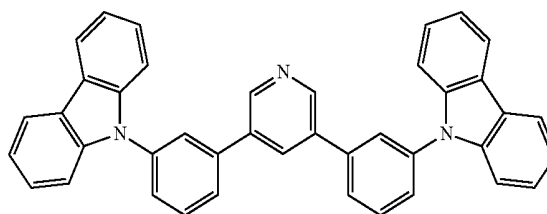
H37



H34

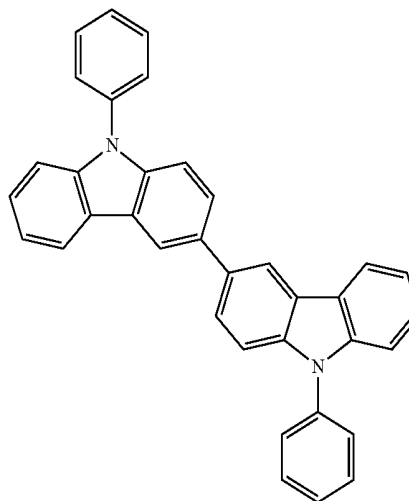
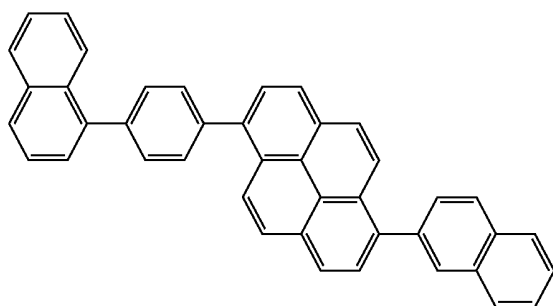


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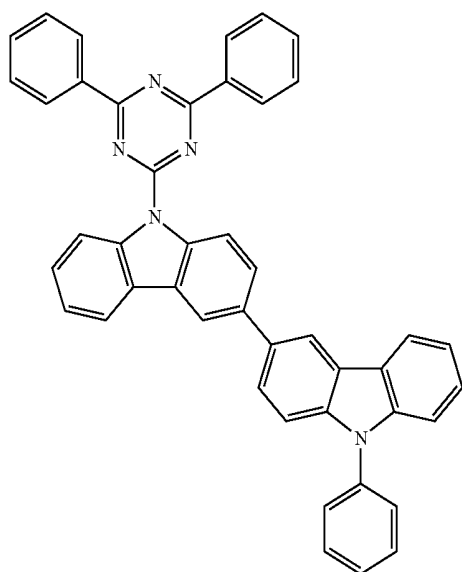


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H35

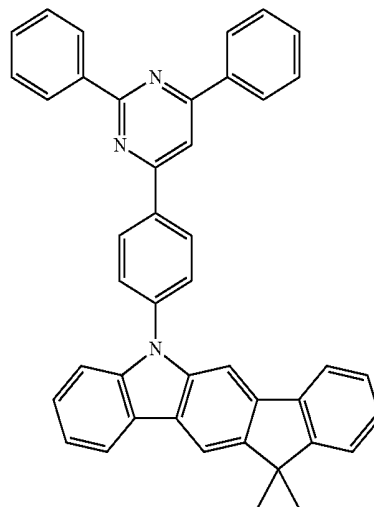


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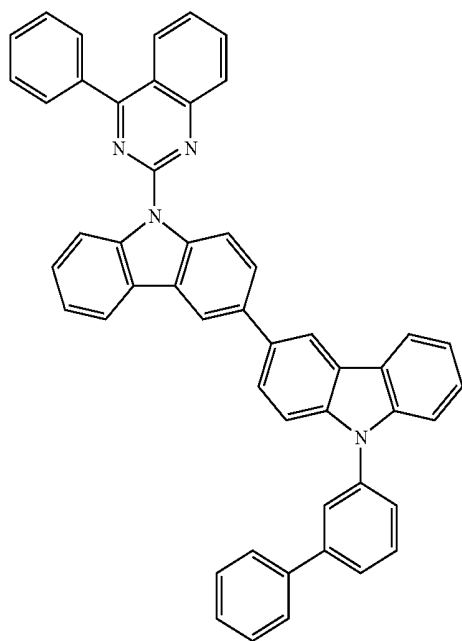
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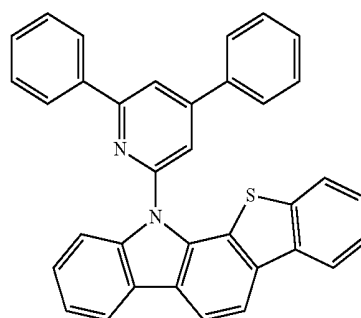


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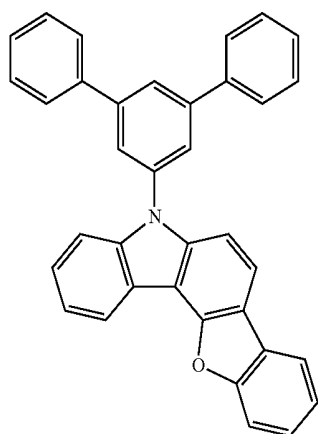
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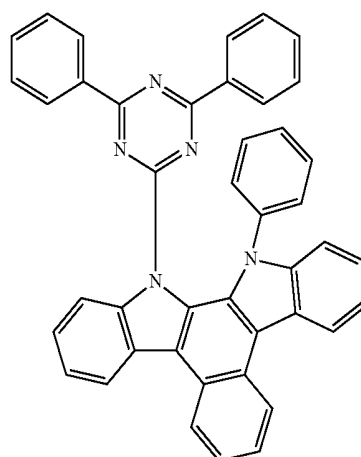
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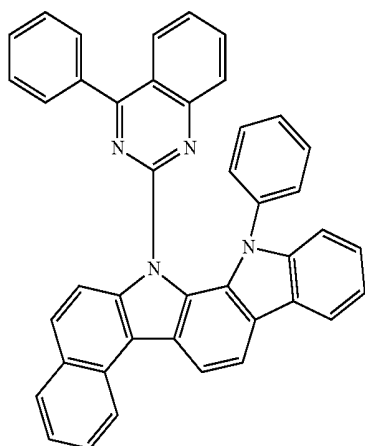


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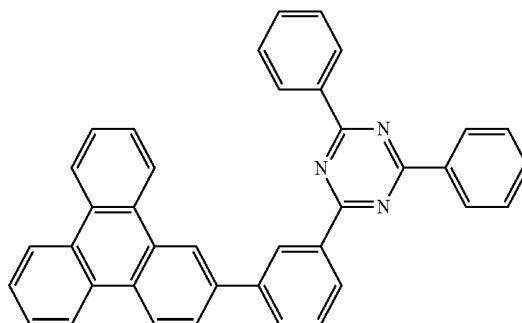
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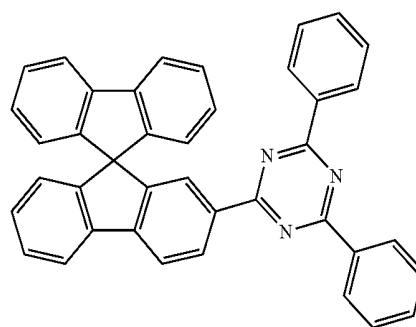


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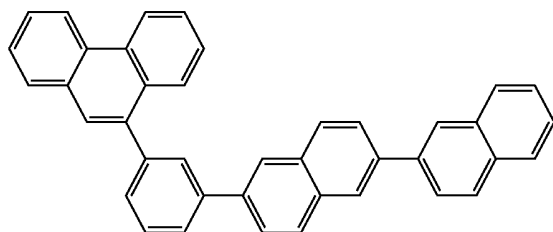


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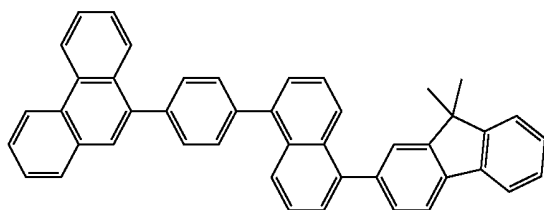


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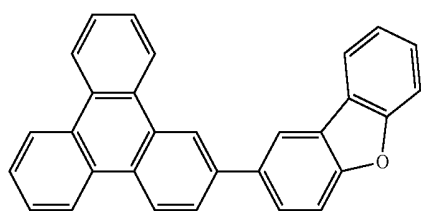
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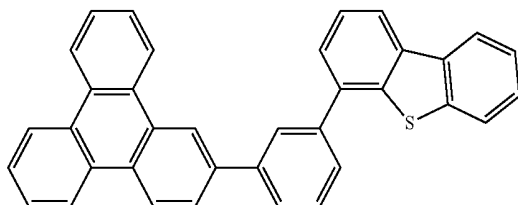
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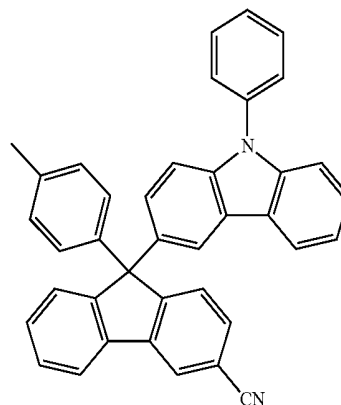
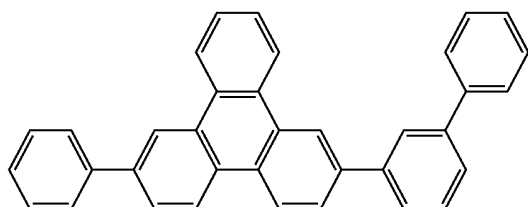
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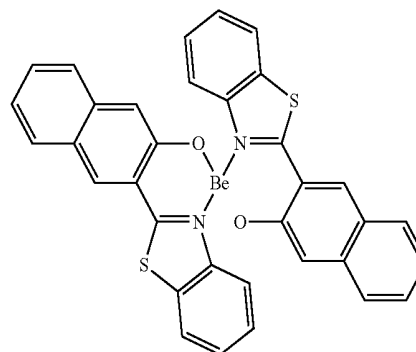
H50



H51

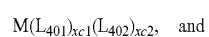


H55



[0284] Phosphorescent dopant included in emission layer in organic layer 150

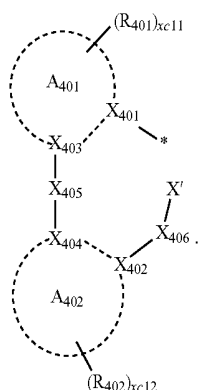
[0285] The phosphorescent dopant may include an organometallic complex represented by Formula 401 below:



<Formula 401>

-continued

<Formula 402>



[0286] In Formulae 401 and 402,

[0287] 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),

[0288] L_{401} may be selected from ligands represented by Formula 402, 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,

[0289] L_{402} may be an organic ligand, and xc2 may be an integer selected 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,

[0290] X_{401} to X_{404} may each independently be nitrogen or carbon,

[0291] 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,

[0292] 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,

[0293] X_{405} may be a single bond, $*-O-*$, $*-S-*$, $*-C(=O)-*$, $*-N(Q_{411})-*$, $*-C(Q_{411})(Q_{412})-*$, $*-C(Q_{411})=C(Q_{412})-*$, $*-C(Q_{411})=*$, or $*=C(Q_{411})=*$, wherein Q_{411} and Q_{412} may be hydrogen, deuterium, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group,

[0294] X_{406} may be a single bond, O, or S,

[0295] R_{401} and R_{402} may each independently be selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1 - C_{20} alkyl group, a substituted or unsubstituted C_1 - C_{20} alkoxy group, a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6 - C_{60} aryl group, a substituted or unsubstituted C_6 - C_{60} aryloxy group, a substituted or unsubstituted C_6 - C_{60} arylthio group, a substituted or unsubstituted C_1 - C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, $-Si(Q_{401})(Q_{402})(Q_{403})$, $-N(Q_{401})(Q_{402})$, $-B(Q_{401})(Q_{402})$, $-C(=O)(Q_{401})$, $-S(=O)_2(Q_{401})$, and $-P(=O)(Q_{401})(Q_{402})$, wherein Q_{401} to Q_{403}

may each independently be selected from a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a C_6 - C_{20} aryl group, and a C_1 - C_{20} heteroaryl group,

[0296] xc11 and xc12 may each independently be an integer selected from 0 to 10, and

[0297] $*$ and $*$ ' in Formula 402 each indicate a binding site to M in Formula 401.

[0298] In one or more embodiments, A_{401} and A_{402} in Formula 402 may each independently be selected from a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, an indene group, a pyrrole group, a thiophene group, a furan group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a quinoxaline group, a quinazoline group, a carbazole group, a benzimidazole group, a benzofuran group, a benzothiothiophene group, an isobenzothiothiophene group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a dibenzofuran group, and a dibenzothiothiophene group.

[0299] 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.

[0300] In one or more embodiments, R_{401} and R_{402} in Formula 402 may each independently be selected from:

[0301] hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

[0302] a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a phenyl group, a naphthyl group, a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, and a norbornenyl group;

[0303] 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 dibenzothiothiophenyl group;

[0304] 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 dibenzothiothiophenyl group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl

group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

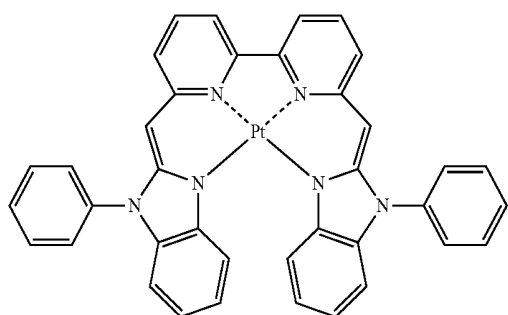
[0305] $-\text{Si}(\text{Q}_{401})(\text{Q}_{402})(\text{Q}_{403})$, $-\text{N}(\text{Q}_{401})(\text{Q}_{402})$, $-\text{B}(\text{Q}_{401})(\text{Q}_{402})$, $-\text{C}(=\text{O})(\text{Q}_{401})$, $-\text{S}(=\text{O})_2(\text{Q}_{401})$, and $-\text{P}(=\text{O})(\text{Q}_{401})(\text{Q}_{402})$,

[0306] wherein Q_{401} to Q_{403} may each independently be selected from a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a biphenyl group, and a naphthyl group, as examples.

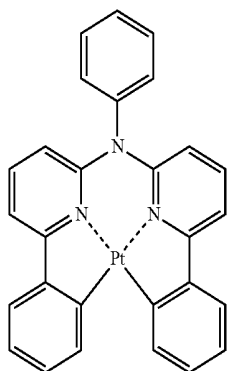
[0307] In one or more embodiments, when xc1 in Formula 401 is two or more, two $\text{A}_{401}(\text{s})$ in two or more $\text{L}_{401}(\text{s})$ may be optionally linked to each other via X_{407} , which is a linking group, or two $\text{A}_{402}(\text{s})$ in two or more $\text{L}_{401}(\text{s})$ may be optionally linked to each other via X_{408} , which is a linking group (see Compounds PD1 to PD4 and PD7). X_{407} and X_{408} may each independently be a single bond, $^*\text{O}^*$, $^*\text{S}^*$, $^*\text{C}(=\text{O})^*$, $^*\text{N}(\text{Q}_{413})^*$, $^*\text{C}(\text{Q}_{413})(\text{Q}_{414})^*$, or $^*\text{C}(\text{Q}_{413})=\text{C}(\text{Q}_{414})^*$ (wherein Q_{413} and Q_{414} may each independently be hydrogen, deuterium, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group), as examples.

[0308] L_{402} in Formula 401 may be a monovalent, divalent, or trivalent organic ligand. For example, L_{402} may be selected from halogen, diketone (for example, acetylacetonate), carboxylic acid (for example, picolinate), $-\text{C}(=\text{O})$, isonitrile, $-\text{CN}$, and phosphorus (for example, phosphine or phosphite), as examples.

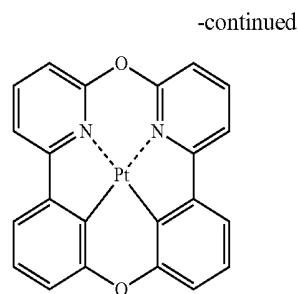
[0309] In one or more embodiments, the phosphorescent dopant may be selected from, for example, Compounds PD1 to PD25, as examples:



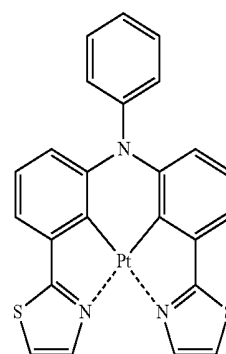
PD1



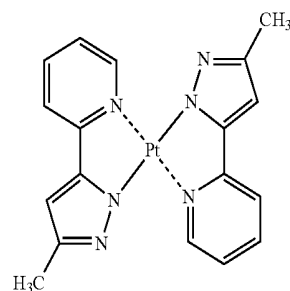
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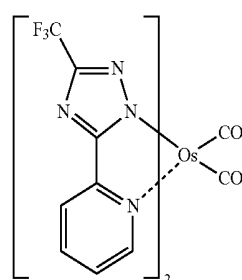
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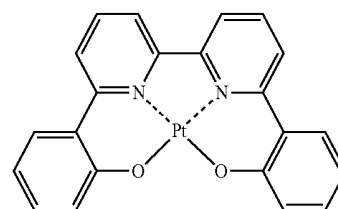
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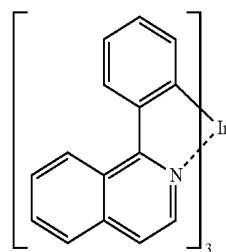
PD5



PD6

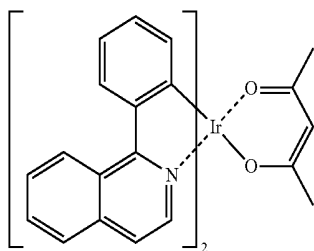


PD7



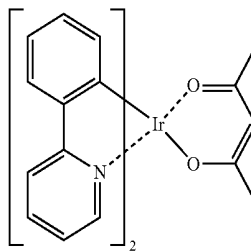
PD8

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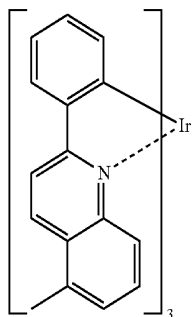


PD9

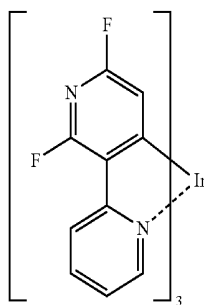
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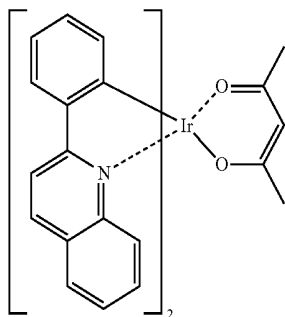
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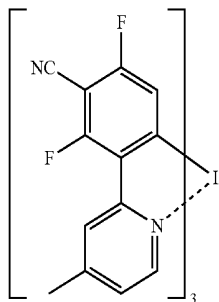
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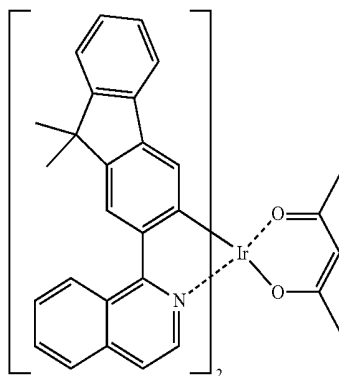
PD15



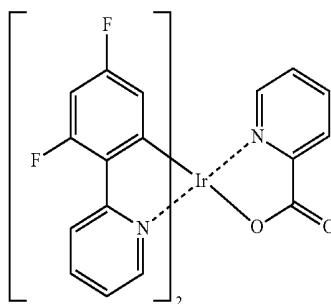
PD11



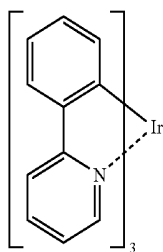
PD16



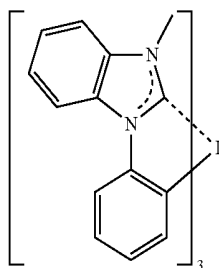
PD12



PD17

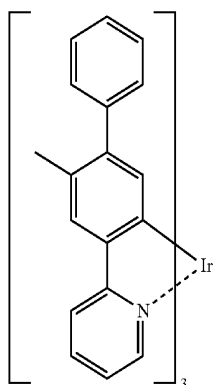
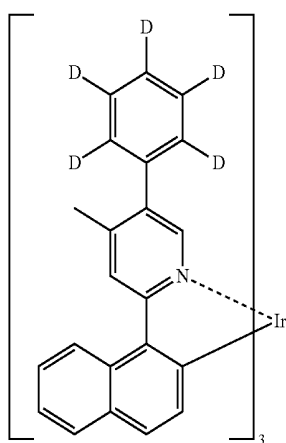
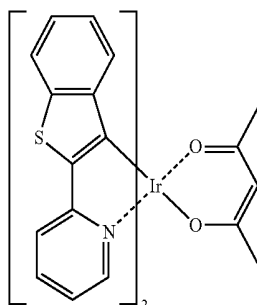
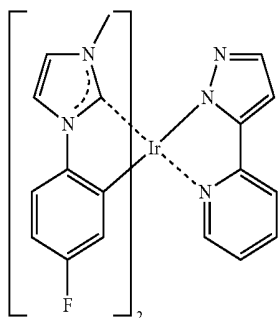


PD13



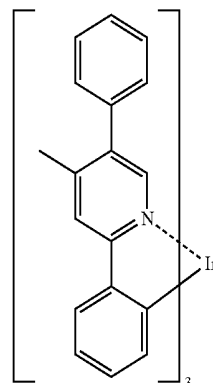
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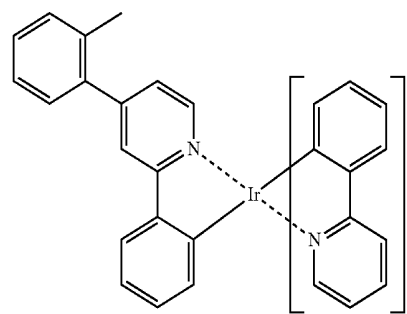
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PD19



PD23

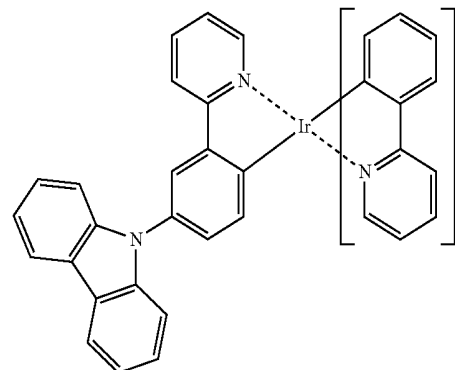
PD20



PD24

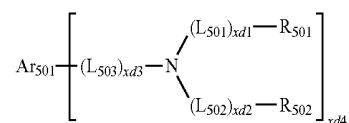
PD25

PD21

**[0310]** Fluorescent dopant in emission layer**[0311]** The fluorescent dopant may include an arylamine compound or a styrylamine compound.**[0312]** The fluorescent dopant may include a compound represented by Formula 501 below.

PD22

<Formula 501>

**[0313]** In Formula 501,**[0314]** Ar_{501} may be a substituted or unsubstituted $\text{C}_5\text{-C}_{60}$ carbocyclic group or a substituted or unsubstituted $\text{C}_1\text{-C}_{60}$ heterocyclic group,**[0315]** L_{501} to L_{503} may each independently be selected from a substituted or unsubstituted $\text{C}_3\text{-C}_{10}$ cycloalkylene group, a substituted or unsubstituted heterocycloalkylene

group, a substituted or unsubstituted C₃-C₁₀ cycloalkenylene group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenylene group, a substituted or unsubstituted C₆-C₆₀ arylene group, a substituted or unsubstituted C₁-C₆₀ heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0316] xd1 to xd3 may each independently be an integer of 0 to 3;

[0317] R₅₀₁ and R₅₀₂ may each independently be selected from a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, and

[0318] xd4 may be an integer of 1 to 6.

[0319] In one or more embodiments, Ar₅₀₁ in Formula 501 may be selected from:

[0320] 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

[0321] 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 C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0322] In one or more embodiments, L₅₀₁ to L₅₀₃ in Formula 501 may each independently be selected from:

[0323] 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 hexacenylene group, a pentacenylene group, a thiophenylenylene group, a furanylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylenylene group, a benzothiophenylenylene group, a benzofuranylenylene group, a dibenzothiophenylenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, dibenzosilolylenylene group, and a pyridinylenylene group; and

[0324] 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 hexacenylene group, a pentacenylene group, a thiophenylenylene group, a furanylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylenylene group, a benzothiophenylenylene group, a benzofuranylenylene group, a dibenzothiophenylenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, dibenzosilolylenylene group, and a pyridinylenylene group; and

nylene group, an anthracenylenylene group, a fluoranthenylenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylene group, a pentacenylene group, a thiophenylenylene group, a furanylene 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, 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 C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a 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.

[0325] In one or more embodiments, R₅₀₁ and R₅₀₂ in Formula 501 may each independently be selected from:

[0326] 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

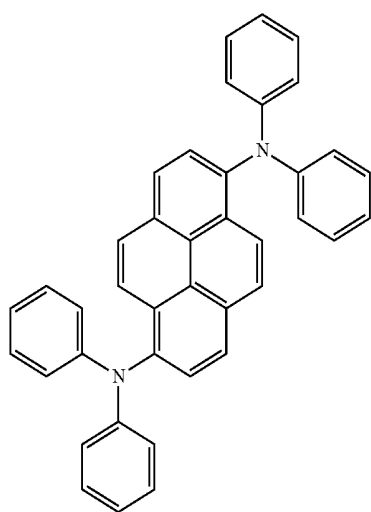
[0327] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, 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 C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a 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

group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, and $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$.

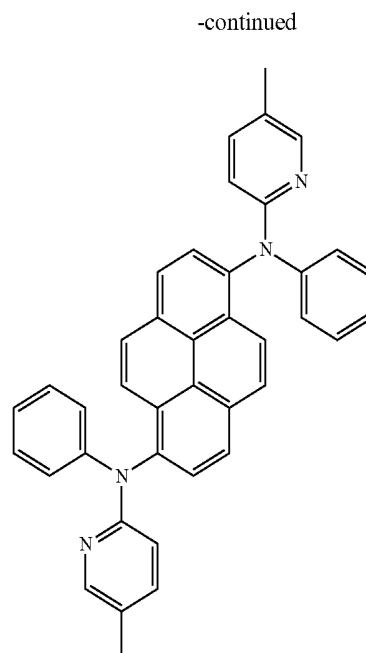
[0328] wherein Q_{31} to Q_{33} may each be selected from a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0329] In one or more embodiments, xd4 in Formula 501 may be 2, as an example.

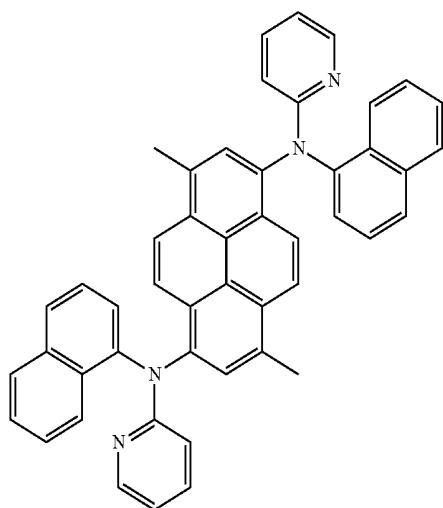
[0330] For example, the fluorescent dopant may be selected from Compounds FD1 to FD22:



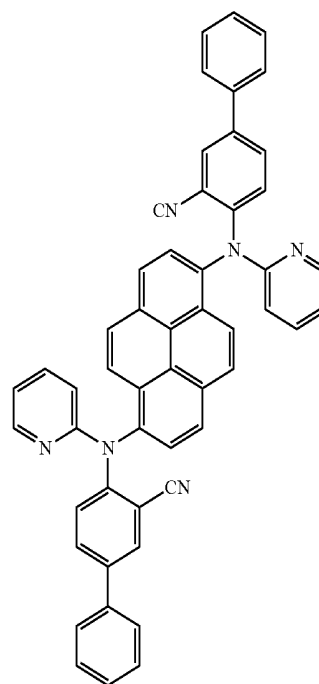
FD1



FD3



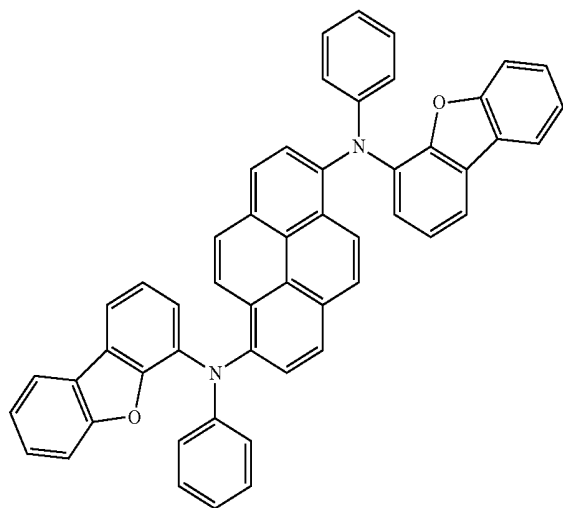
FD2



FD4

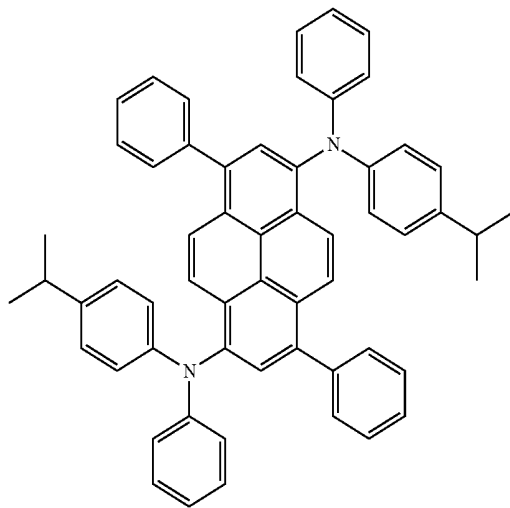
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FD5

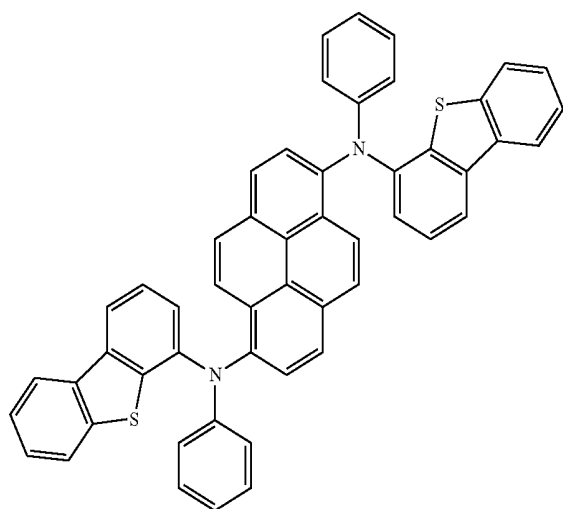


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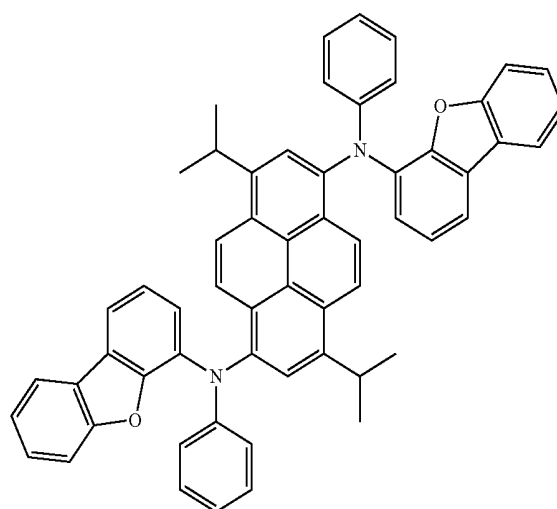
FD8



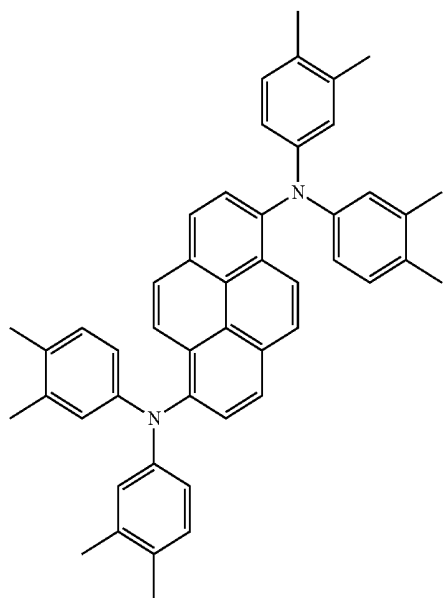
FD6



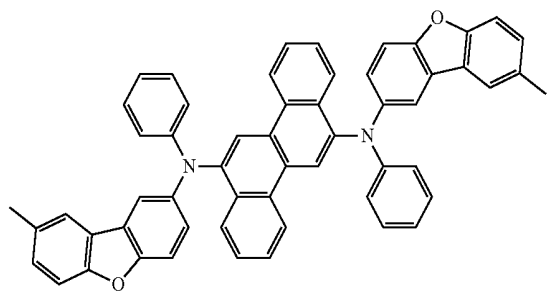
FD9



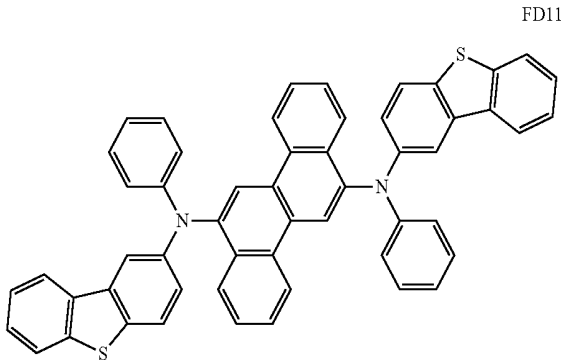
FD7



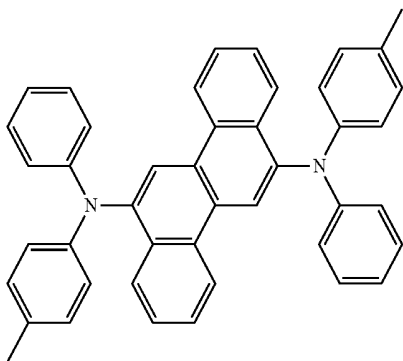
FD10



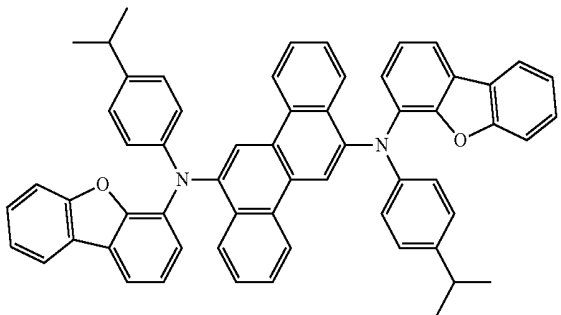
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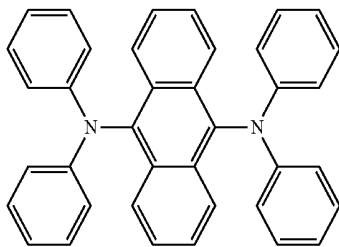
FD12



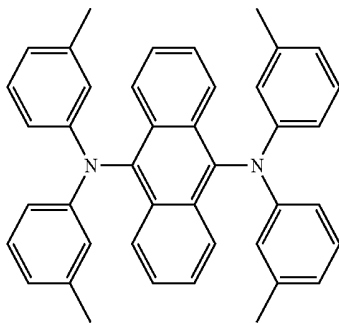
FD13



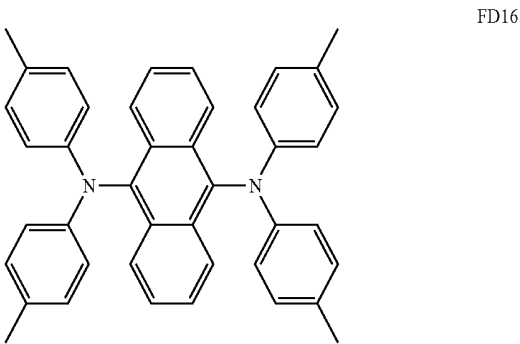
FD14



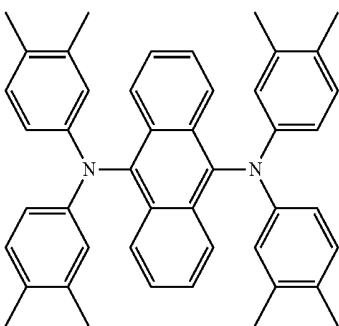
FD15



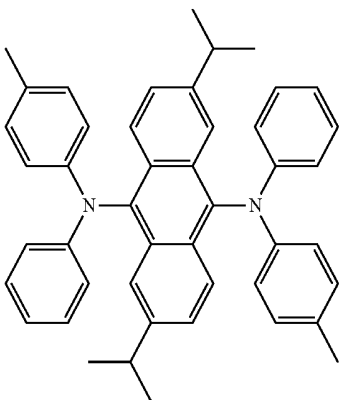
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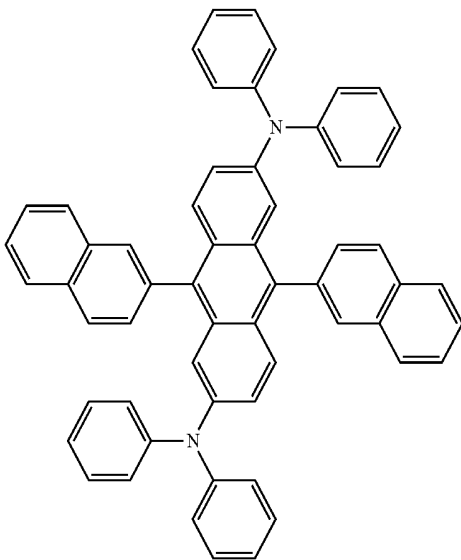
FD17



FD18

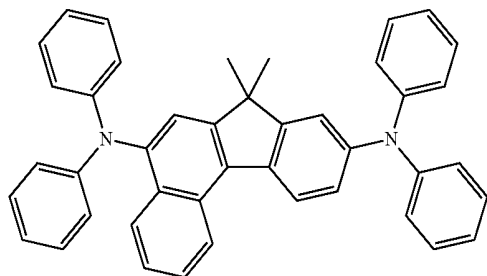


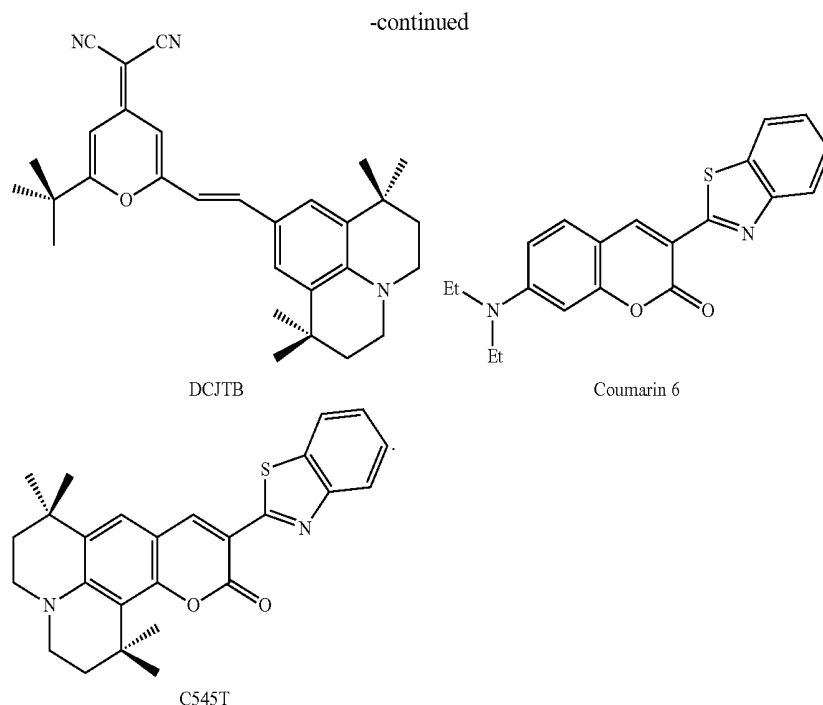
FD19



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FD20





[0332] Electron transport region in organic layer 150

[0333] 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.

[0334] 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, as examples.

[0335] 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.

[0336] The electron transport region may include at least one of the heterocyclic compounds.

[0337] In one or more embodiments, the electron transport region may include an electron transport layer. The electron transport layer may include at least one of the heterocyclic compounds, as examples.

[0338] 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.

[0339] The term “ 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.

[0340] For example, the π electron-depleted nitrogen-containing ring may be i) a 5-membered to 7-membered hetero monocyclic group having at least one $*-N=*'$ moiety, ii) a heteropoly cyclic group in which two or more 5-membered to 7-membered hetero monocyclic groups each having at least one $*-N=*'$ moiety are condensed with

each other, or iii) a heteropoly cyclic group in which at least one of 5-membered to 7-membered hetero monocyclic groups, each having at least one $*-N=*'$ moiety, is condensed with at least one C_5 - C_{60} carbocyclic group.

[0341] Examples of the π electron-depleted nitrogen-containing ring include an imidazole, a pyrazole, a thiazole, an isothiazole, an oxazole, an isoxazole, a pyridine, a pyrazine, a pyrimidine, a pyridazine, an indazole, a purine, a quinoline, an isoquinoline, a benzoquinoline, a phthalazine, a naphthyridine, a quinoxaline, a quinazoline, a cinnoline, a phenanthridine, an acridine, a phenanthroline, a phenazine, a benzimidazole, an isobenzothiazole, a benzoxazole, an isobenzoxazole, a triazole, a tetrazole, an oxadiazole, a triazine, thiadiazol, an imidazopyridine, an imidazopyrimidine, and an azacarbazole.

[0342] For example, the electron transport region may include a compound represented by Formula 601:



[0343] In Formula 601,

[0344] 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,

[0345] $xe11$ may be 1, 2, or 3,

[0346] 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;

[0347] $xe1$ may be an integer selected from 0 to 5,

[0348] 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 unsub-

stituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(Q₆₀₁)(Q₆₀₂)(Q₆₀₃), —C(=O)(Q₆₀₁), —S(=O)₂(Q₆₀₁), and —P(=O)(Q₆₀₁)(Q₆₀₂),

[0349] Q₆₀₁ to Q₆₀₃ may each independently be a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group, and

[0350] xe21 may be an integer selected from 1 to 5.

[0351] In one or more embodiments, at least one of Ar₆₀₁(s) in the number of xe11 and/or at least one of R₆₁₀(s) in the number of xe21 may include the π electron-depleted nitrogen-containing ring.

[0352] In one or more embodiments, ring Ar₆₀₁ in Formula 601 may be selected from:

[0353] a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, a dibenzothiophene group, a carbazole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, a phenanthroline group, a phenazine group, a benzimidazole group, an iso-benzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, thiadiazole group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group; and

[0354] a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, a dibenzothiophene group, a carbazole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, a phenanthroline group, a phenazine group, a benzimidazole group, an iso-benzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, 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 C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group,

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂),

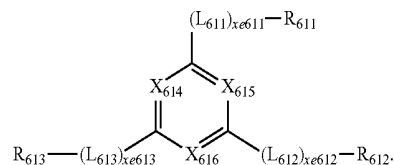
[0355] wherein Q₃₁ to Q₃₃ may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0356] When xe11 in Formula 601 is two or more, two or more Ar₆₀₁(s) may be linked to each other via a single bond.

[0357] In one or more embodiments, Ar₆₀₁ in Formula 601 may be an anthracene group.

[0358] In one or more embodiments, a compound represented by Formula 601 may be represented by Formula 601-1:

<Formula 601-1>



[0359] In Formula 601-1,

[0360] 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,

[0361] L₆₁₁ to L₆₁₃ may be each independently substantially the same as described in connection with L₆₀₁,

[0362] xe611 to xe613 may be each independently substantially the same as described in connection with xe1,

[0363] R₆₁₁ to R₆₁₃ may be each independently substantially the same as described in connection with R₆₀₁,

[0364] 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.

[0365] In one or more embodiments, L₆₀₁ and L₆₁₁ to L₆₁₃ in Formulae 601 and 601-1 may each independently be selected from:

[0366] 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 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 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 benzimidazolylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolylene group; and

[0367] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, a pyridinylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isoxazolylene group, a thiadiazolylene group, an oxadiazolylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a triazinylene group, a quinolylene group, an isoquinolylene group, a benzoquinolylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, an isobenzothiazolylene group, a benzoxazolylene group, a triazolylene group, a tetrazolylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a 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 quinolyl group, an isoquinolyl group, a benzoquinolyl 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, as examples.

[0368] In one or more embodiments, xe1 and xe611 to xe613 in Formulae 601 and 601-1 may each independently be 0, 1, or 2.

[0369] In one or more embodiments, R₆₀₁ and R₆₁₁ to R₆₁₃ in Formula 601 and 601-1 may each independently be selected from:

[0370] 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 quinolyl group, an isoquinolyl group, a benzoquinolyl 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;

[0371] 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 quinolyl group, an isoquinolyl group, a benzoquinolyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a 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 quinolyl group, an isoquinolyl group, a benzoquinolyl 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, as examples.

azolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group; and

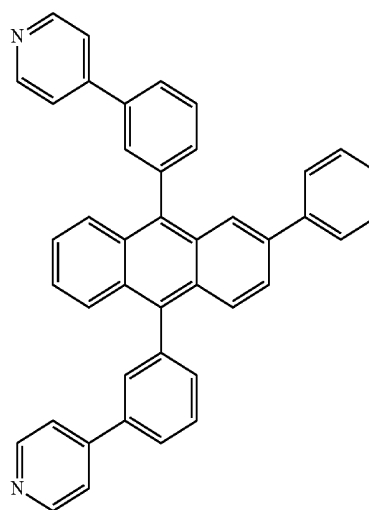
[0372] $-\text{S}(=\text{O})_2(\text{Q}_{601})$, and $-\text{P}(=\text{O})(\text{Q}_{601})(\text{Q}_{602})$,

[0373] wherein Q_{601} and Q_{602} are substantially the same as described above.

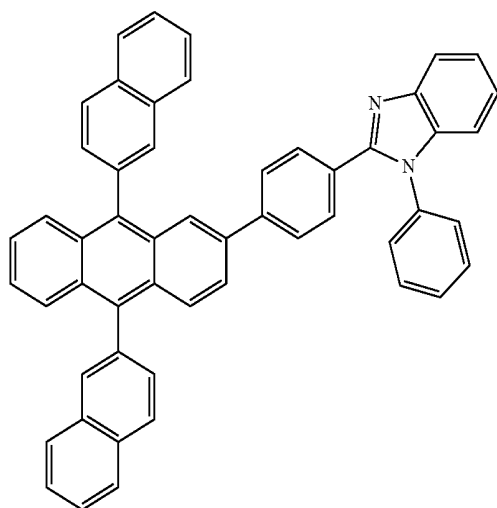
[0374] The electron transport region may include at least one compound selected from Compounds ET1 to ET36, as examples:

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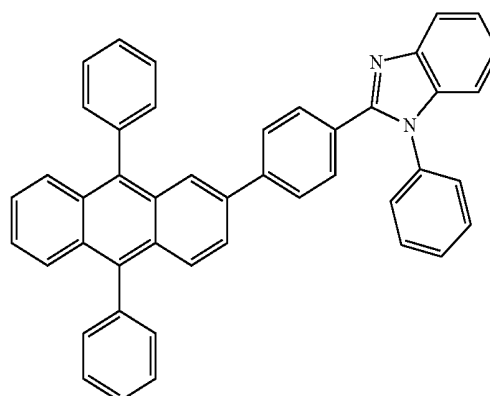
ET3



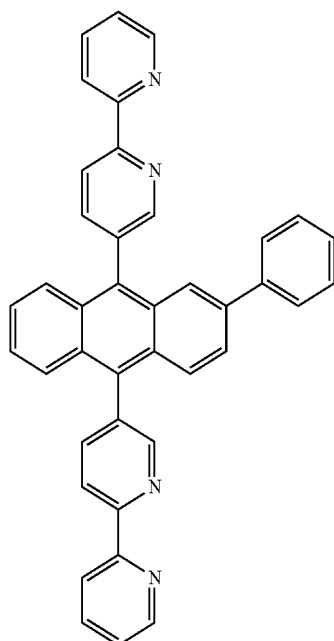
ET1



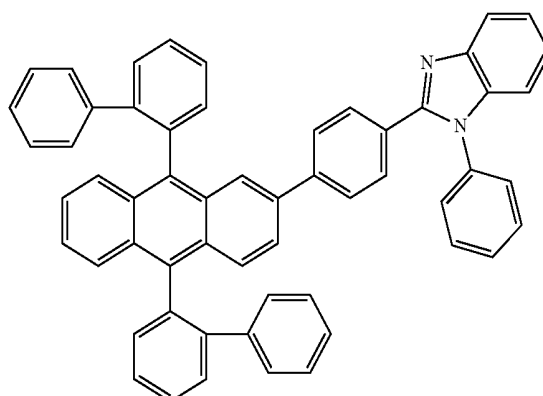
ET4



ET2

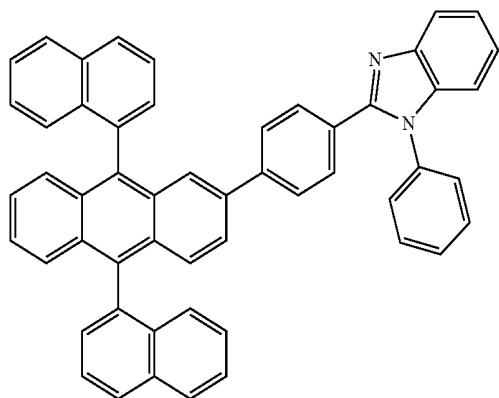


ET5



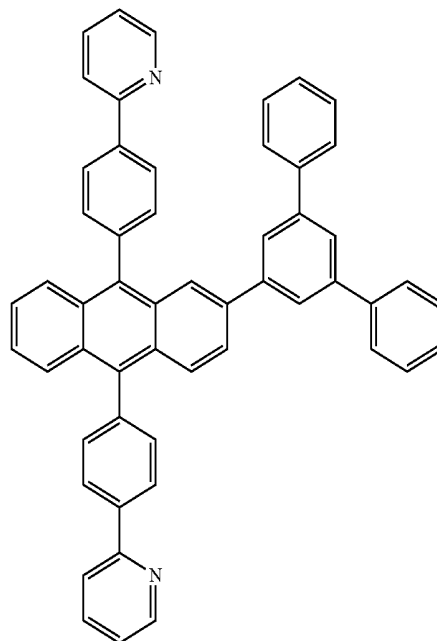
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ET6

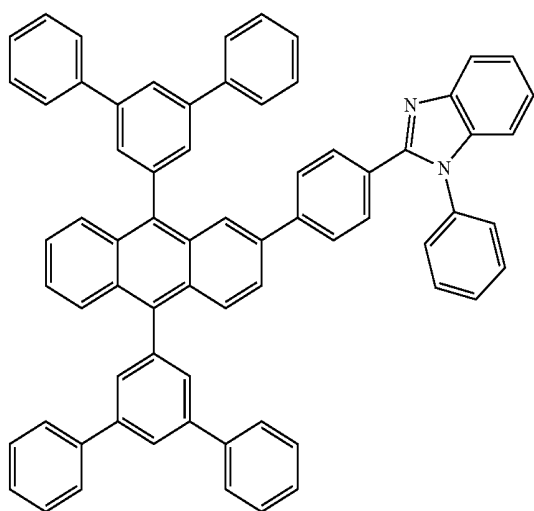


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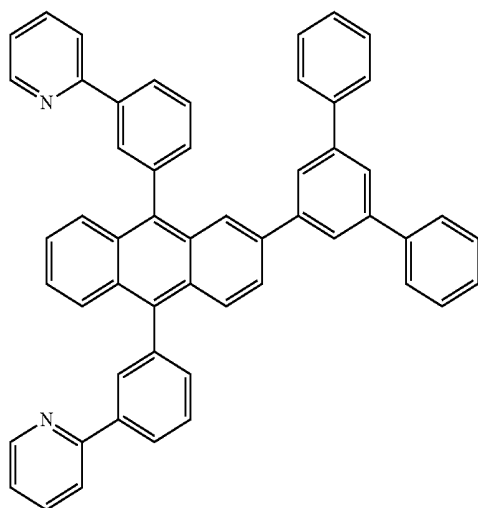
ET9



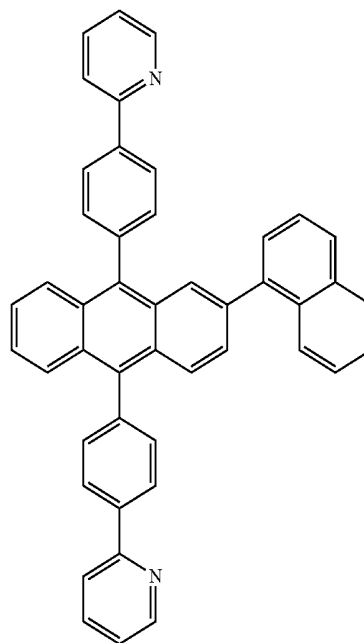
ET7



ET8

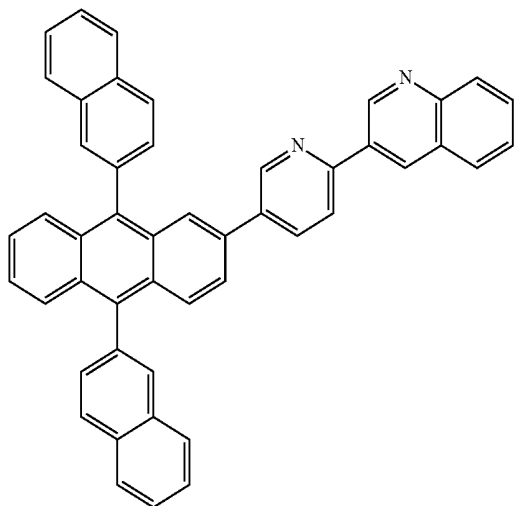


ET10



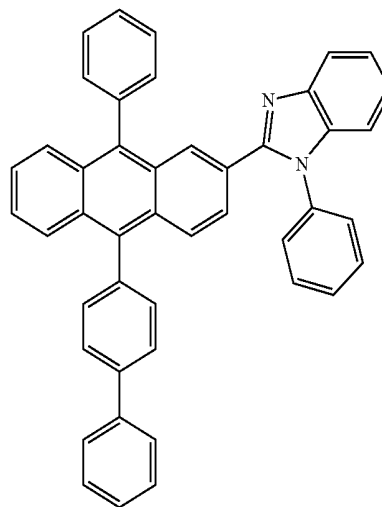
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ET11

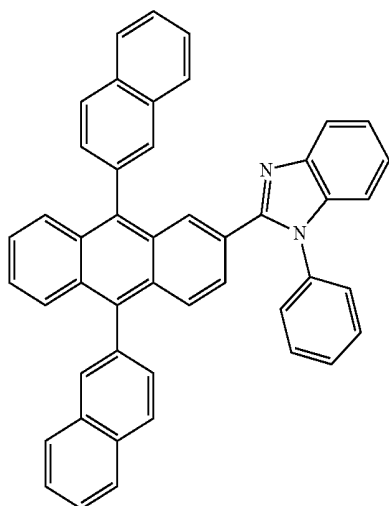


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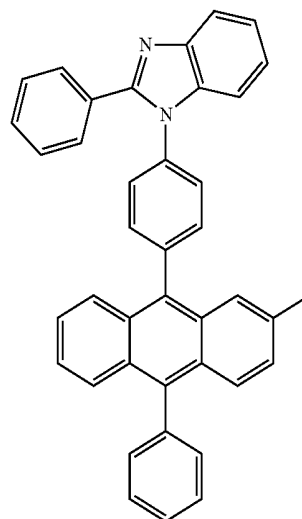
ET14



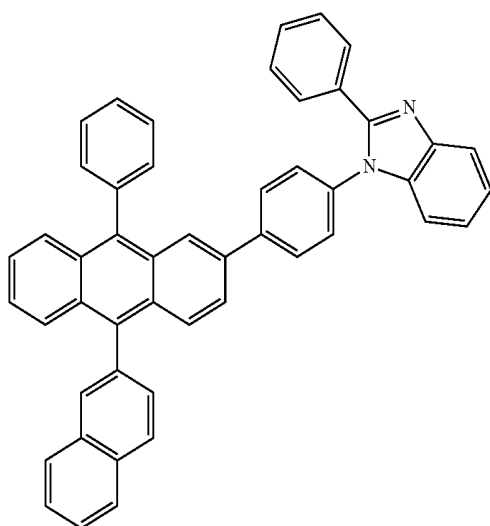
ET12



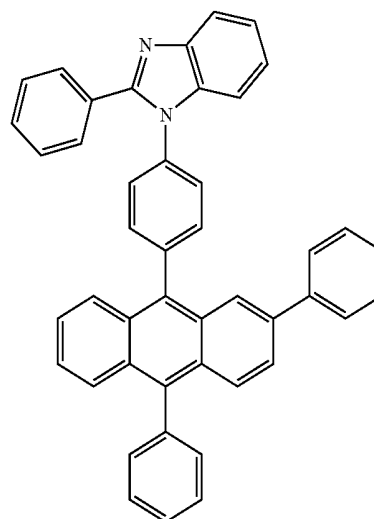
ET15



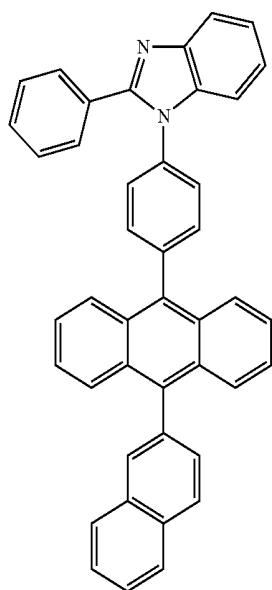
ET13



ET16

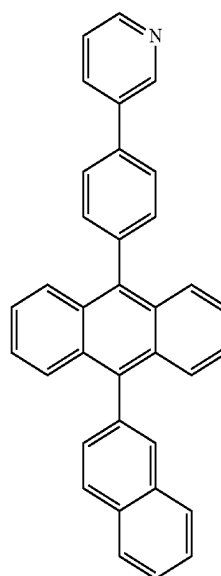


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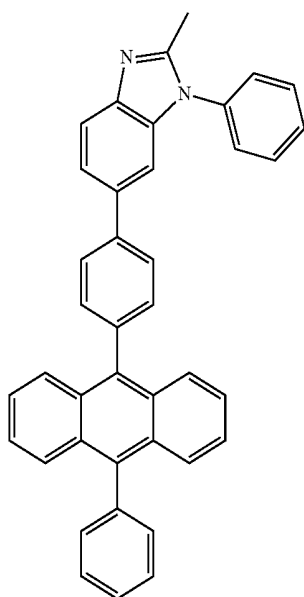
ET17

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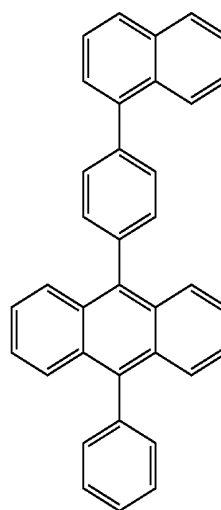


ET20

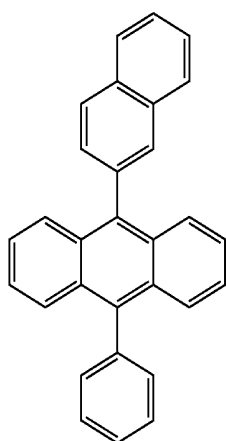
ET18



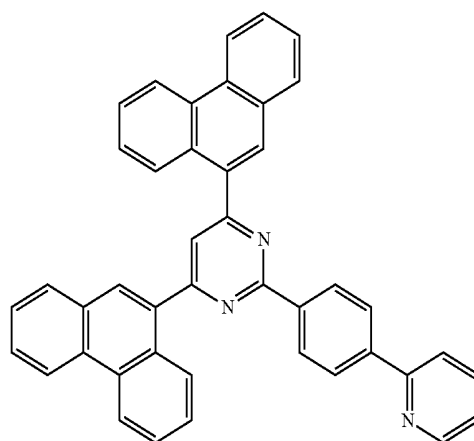
ET21



ET19

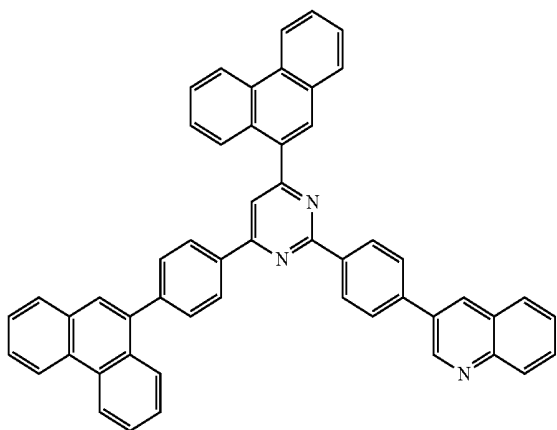


ET22



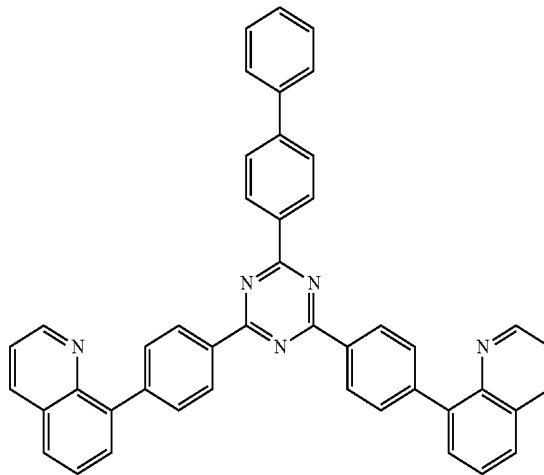
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ET23

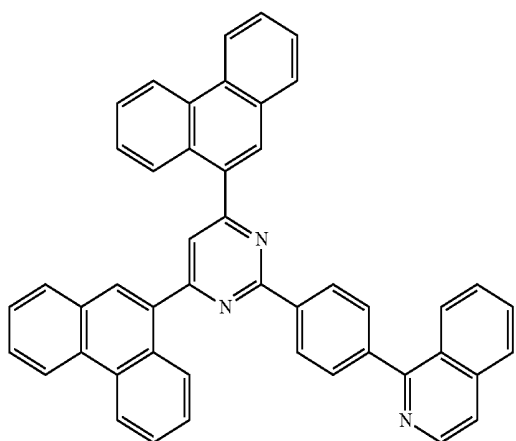


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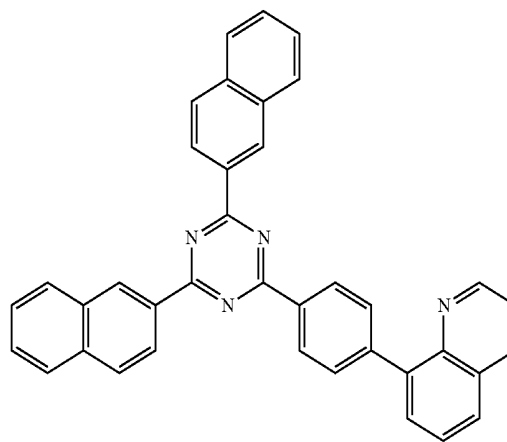
ET26



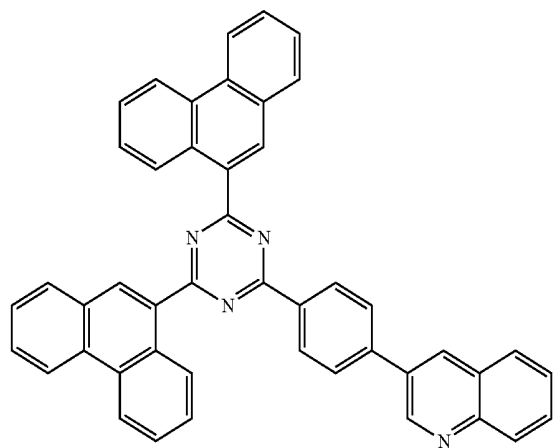
ET24



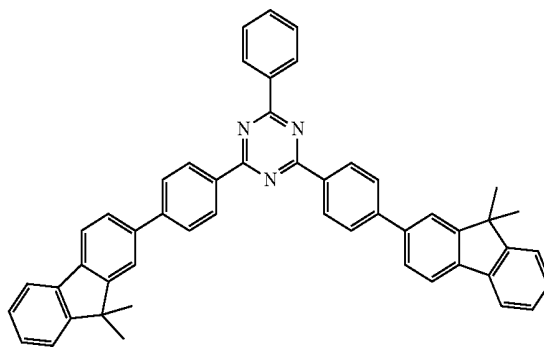
ET27



ET25

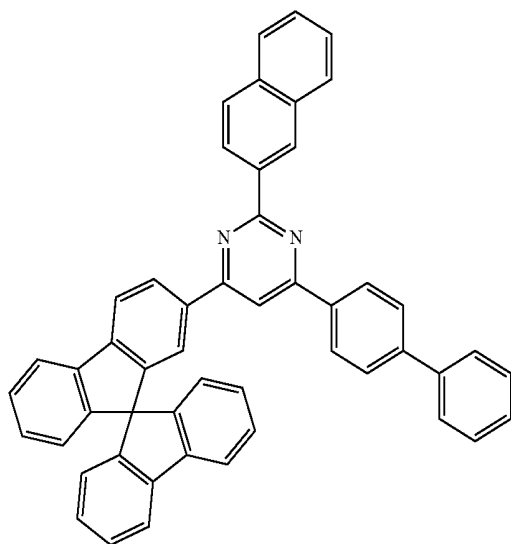


ET28



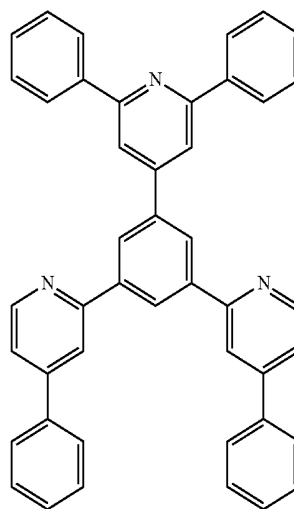
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ET29

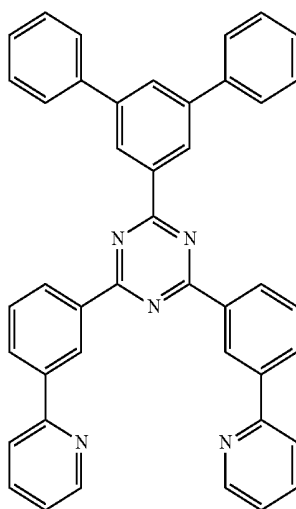


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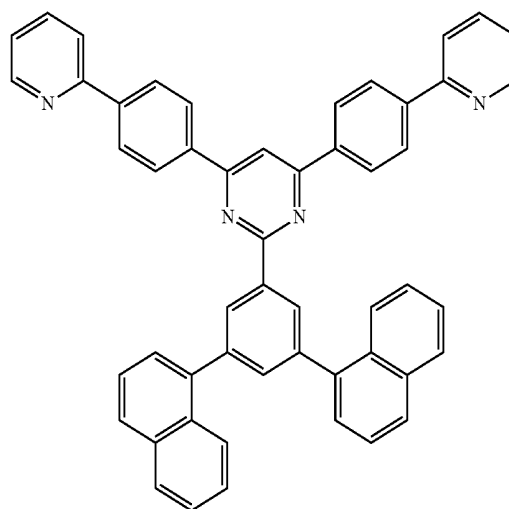
ET32



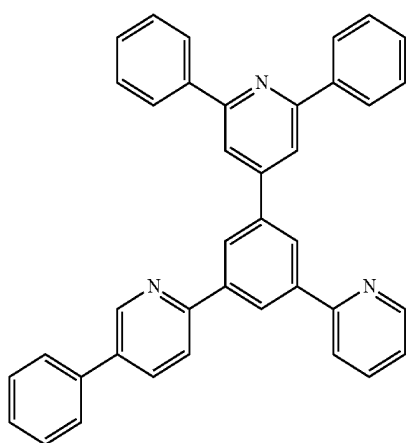
ET30



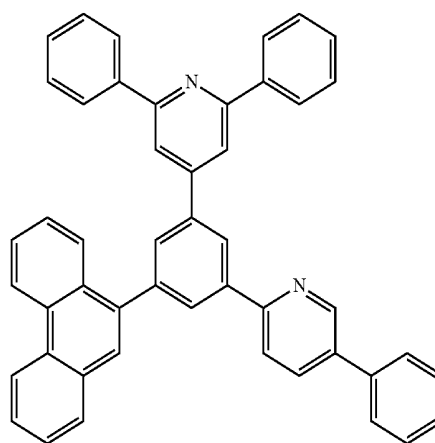
ET33



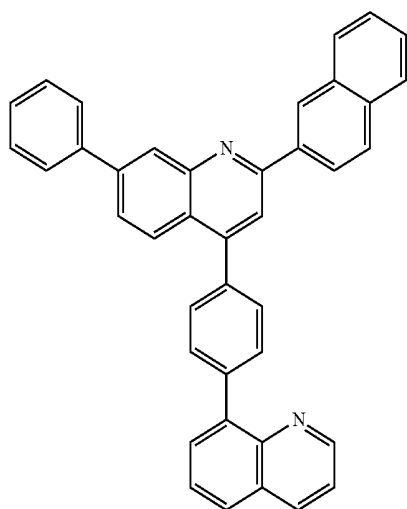
ET31



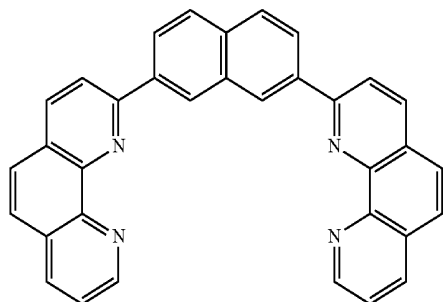
ET34



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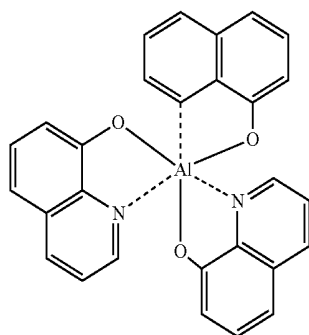
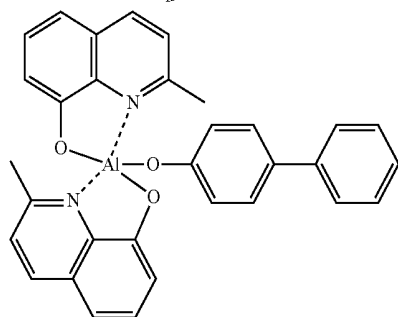


ET35



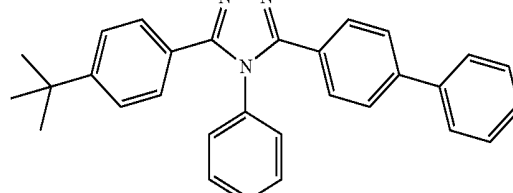
ET36

[0375] 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-1,2,4-triazole (TAZ), and NTAZ:

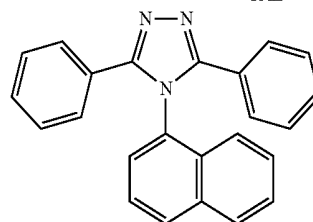
Alq₃

BAlq

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TAZ



NTAZ

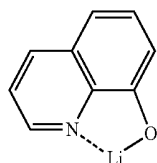
[0376] The thickness of the buffer layer, the hole blocking layer, or the electron control layer may each independently be in a range of about 20 Å to about 1,000 Å, or, for example, about 30 Å to about 300 Å. When the thicknesses of the buffer layer, the hole blocking layer, and the electron control 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.

[0377] A thickness of the electron transport layer may be in a range of about 100 Å to about 1,000 Å, or, for example, about 150 Å to about 500 Å. When the thickness of the electron transport layer is within the range described above, the electron transport layer may have satisfactory electron transport characteristics without a substantial increase in driving voltage.

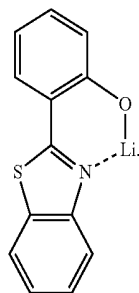
[0378] The electron transport region (for example, the electron transport layer in the electron transport region) may further include, in addition to the materials described above, a metal-containing material.

[0379] The metal-containing material may include at least one selected from an alkali metal complex and an alkaline earth-metal complex. The alkali metal complex may include a metal ion selected from an Li ion, a Na ion, a K ion, a Rb ion, and a Cs ion. The alkaline earth-metal complex may include a metal ion selected from a Be ion, a Mg ion, a Ca ion, an Sr ion, and a Ba ion. A ligand coordinated with the metal ion of the alkali metal complex or the alkaline earth-metal complex may be selected from a hydroxy quinoline, a hydroxy isoquinoline, a hydroxy benzoquinoline, a hydroxy acridine, a hydroxy phenanthridine, a hydroxy phenylan oxazole, a hydroxy phenylthiazole, a hydroxy diphenylan oxadiazole, a hydroxy diphenylthiadiazol, a hydroxy phenylpyridine, a hydroxy phenylbenzimidazole, a hydroxy phenylbenzothiazole, a bipyridine, a phenanthroline, and a cyclopentadiene, as examples.

[0380] For example, the metal-containing material may include a Li complex. The Li complex may include, for example, Compound ET-D1 (lithium quinolate, LiQ) or ET-D2:



ET-D1



ET-D2

[0381] The electron transport region may include an electron injection layer that facilitates injection of electrons from the second electrode **190**. The electron injection layer may directly contact the second electrode **190**.

[0382] 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.

[0383] The electron injection layer may include alkali metal, alkaline earth metal, 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.

[0384] The alkali metal may be selected from Li, Na, K, Rb, and Cs. In one or more embodiments, the alkali metal may be Li, Na, or Cs. In one or more embodiments, the alkali metal may be Li or Cs, as examples.

[0385] The alkaline earth metal may be selected from Mg, Ca, Sr, and Ba.

[0386] The rare-earth metal may be selected from Sc, Y, Ce, Tb, Yb, and Gd.

[0387] 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 rare-earth metal.

[0388] The alkali metal compound may be selected from alkali metal oxides, such as Li_2O , Cs_2O , or K_2O , and alkali metal halides, such as LiF , NaF , CsF , KF , LiI , NaI , CsI , or KI . In one or more embodiments, the alkali metal compound may be selected from LiF , Li_2O , NaF , LiI , NaI , CsI , and KI , as examples.

[0389] The alkaline earth-metal compound may be selected from alkaline earth-metal compounds, such as BaO , SrO , CaO , $\text{Ba}_x\text{Sr}_{1-x}\text{O}$ ($0 < x < 1$), or $\text{Ba}_x\text{Ca}_{1-x}\text{O}$ ($0 < x < 1$). In one or more embodiments, the alkaline earth-metal compound may be selected from BaO , SrO , and CaO , as examples.

[0390] The rare-earth metal compound may be selected from YbF_3 , ScF_3 , ScO_3 , Y_2O_3 , Ce_2O_3 , GdF_3 , and TbF_3 . In

one or more embodiments, the rare-earth metal compound may be selected from YbF_3 , ScF_3 , TbF_3 , YbI_3 , ScI_3 , and TbI_3 , as examples.

[0391] 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, and the rare-earth metal complex may each independently be selected from hydroxy quinoline, hydroxy isoquinoline, hydroxy benzoquinoline, hydroxy acridine, hydroxy phenanthridine, hydroxy phenylan oxazole, hydroxy phenylthiazole, hydroxy diphenylan oxadiazole, hydroxy diphenylthiadiazol, hydroxy phenylpyridine, hydroxy phenylbenzimidazole, hydroxy phenylbenzothiazole, bipyridine, phenanthroline, and cyclopentadiene, as examples.

[0392] The electron injection layer may consist of alkali metal, alkaline earth metal, 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, alkali metal, alkaline earth metal, 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.

[0393] A thickness of the electron injection layer may be in a range of about 1 Å to about 100 Å, for example, about 3 Å to about 90 Å. When the thickness of the electron injection layer is within the range described above, the electron injection layer may have satisfactory electron injection characteristics without a substantial increase in driving voltage.

[0394] Second electrode **190**

[0395] The second electrode **190** may be disposed on the organic layer **150** having such a structure. The second electrode **190** may be a cathode that is an electron injection electrode, and in this regard, a material for forming the second electrode **190** may be a material having a low work function, and such a material may be metal, alloy, an electrically conductive compound, or a combination thereof.

[0396] 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, as examples. The second electrode **190** may be a transmissive electrode, a semi-transmissive electrode, or a reflective electrode.

[0397] The second electrode **190** may have a single-layered structure, or a multi-layered structure including two or more layers.

[0398] Description of FIGS. 2 to 4

[0399] An organic light-emitting device **20** of FIG. 2 may include a first capping layer **210**, a first electrode **110**, an organic layer **150**, and a second electrode **190** which are sequentially stacked in this stated order. An organic light-emitting device **30** of FIG. 3 may include a first electrode **110**, an organic layer **150**, a second electrode **190**, and a

second capping layer 220 which are sequentially stacked in this stated order. An organic light-emitting device 40 of FIG. 4 may include a first capping layer 210, a first electrode 110, an organic layer 150, a second electrode 190, and a second capping layer 220.

[0400] Regarding FIGS. 2 to 4, the first electrode 110, the organic layer 150, and the second electrode 190 may be understood by referring to the description presented in connection with FIG. 1.

[0401] In the organic layer 150 of each of the organic light-emitting devices 20 and 40, light generated in an emission layer may pass through the first electrode 110, which may be a semi-transmissive electrode or a transmissive electrode, and the first capping layer 210 toward the outside. In the organic layer 150 of each of the organic light-emitting devices 30 and 40, light generated in an emission layer may pass through the second electrode 190, which is a semi-transmissive electrode or a transmissive electrode, and the second capping layer 220 toward the outside.

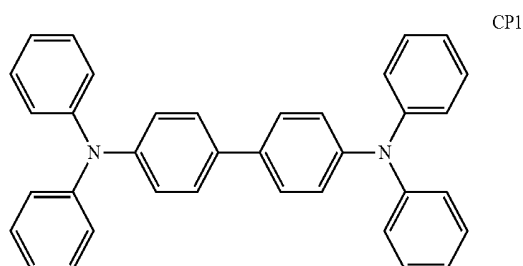
[0402] The first capping layer 210 and the second capping layer 220 may increase external luminescent efficiency according to the principle of constructive interference.

[0403] The first capping layer 210 and the second capping layer 220 may each independently be an organic capping layer including an organic material, an inorganic capping layer including an inorganic material, or a composite capping layer including an organic material and an inorganic material.

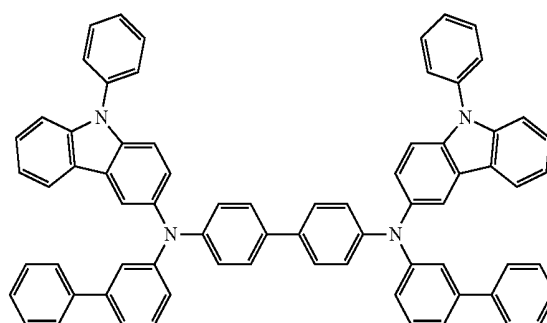
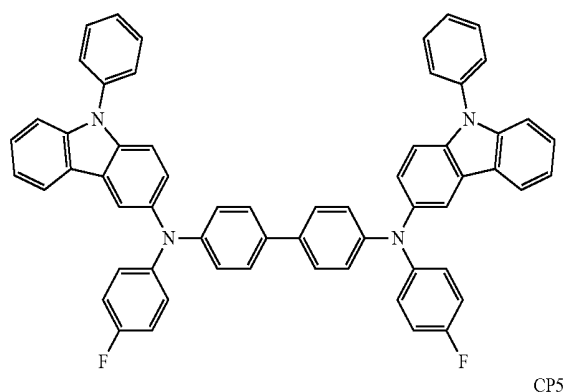
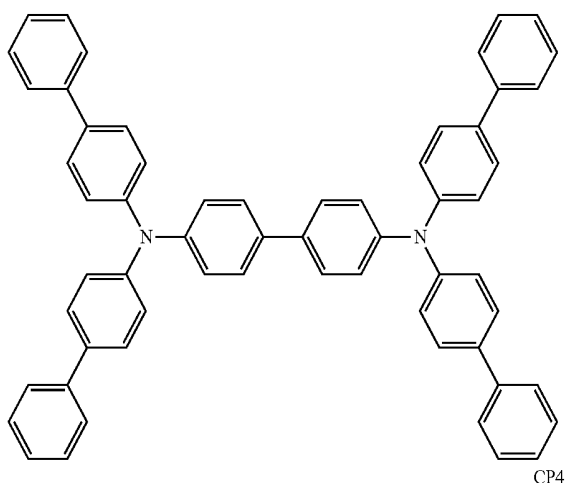
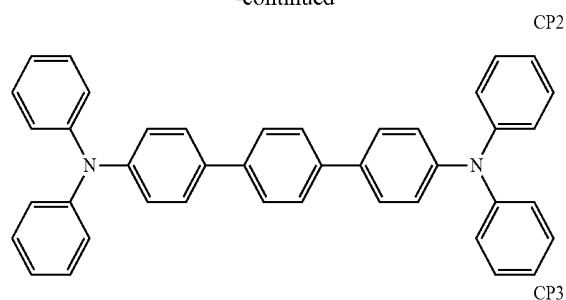
[0404] At least one selected from the first capping layer 210 and the second capping layer 220 may each independently include at least one material selected from a carbocyclic compound, a heterocyclic compound, an amine-based compound, a porphyrine derivative, a phthalocyanine derivative, a naphthalocyanine derivative, an alkali metal complex, and an alkaline earth-based complex. The carbocyclic compound, the heterocyclic compound, and the amine-based compound may be optionally substituted with a substituent containing at least one element selected from O, N, S, Se, Si, F, Cl, Br, and I. In one or more embodiments, at least one selected from the first capping layer 210 and the second capping layer 220 may independently include an amine-based compound.

[0405] In one or more embodiments, at least one selected from the first capping layer 210 and the second capping layer 220 may independently include the compound represented by Formula 201 or the compound represented by Formula 202.

[0406] In one or more embodiments, at least one selected from the first capping layer 210 and the second capping layer 220 may independently include a compound selected from Compounds HT28 to HT33 and Compounds CP1 to CP5, as examples.



-continued



[0407] Hereinbefore, the organic light-emitting device according to an embodiment has been described in connection with FIGS. 1-4. The organic light-emitting device may have other configurations.

[0408] Respective layers constituting the hole transport region, an emission layer, and respective 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.

[0409] When the respective layers of the hole transport region, the emission layer, and the respective layers of the electron transport region are formed by deposition, the deposition may be performed at a deposition temperature of about 100 to about 500° C., at a vacuum degree of about 10^{-8} to about 10^{-3} torr, and at a deposition rate of about 0.01 to about 100 Å/sec by taking into account a material for forming a layer to be deposited and the structure of a layer to be formed.

[0410] 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 200° C., depending on a material to be included in a layer and the structure of each layer to be formed.

[0411] General definition of substituents

[0412] The term “C₁-C₆₀ alkyl group” as used herein refers to a linear or branched saturated aliphatic hydrocarbon monovalent group having 1 to 60 carbon atoms, and non-limiting examples thereof include a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, a pentyl group, an iso-amyl group, and a hexyl group. The term “C₁-C₆₀ alkylene group” as used herein refers to a divalent group having the same structure as the C₁-C₆₀ alkyl group.

[0413] The term “C₂-C₆₀ alkenyl group” as used herein refers to a hydrocarbon group formed by substituting at least one carbon-carbon double bond in the middle or at the terminus of the C₂-C₆₀ alkyl group, and non-limiting examples thereof include an ethenyl group, a propenyl group, and a butenyl group. The term “C₂-C₆₀ alkenylene group” as used herein refers to a divalent group having the same structure as the C₂-C₆₀ alkenyl group.

[0414] The term “C₂-C₆₀ alkynyl group” as used herein refers to a hydrocarbon group formed by substituting at least one carbon-carbon triple bond in the middle or at the terminus of the C₂-C₆₀ alkyl group, and non-limiting examples thereof include an ethynyl group and a propynyl group. The term “C₂-C₆₀ alkynylene group” as used herein refers to a divalent group having the same structure as the C₂-C₆₀ alkynyl group.

[0415] The term “C₁-C₆₀ alkoxy group” as used herein refers to a monovalent group represented by —OA₁₀₁ (wherein A₁₀₁ is the C₁-C₆₀ alkyl group), and non-limiting examples thereof include a methoxy group, an ethoxy group, and an isopropoxy group.

[0416] The term “C₃-C₁₀ cycloalkyl group” as used herein refers to a monovalent saturated hydrocarbon monocyclic group having 3 to 10 carbon atoms, and non-limiting examples thereof include a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. The term “C₃-C₁₀ cycloalkylene group” as used herein refers to a divalent group having the same structure as the C₃-C₁₀ cycloalkyl group.

[0417] The term “C₁₀-C₁₀ heterocycloalkyl group” as used herein refers to a monovalent saturated monocyclic group having at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom and 1 to 10 carbon atoms, and non-limiting examples thereof include a 1,2,3,4-oxatriazolidinyl group, a tetrahydrofuranyl group, and a tetrahydrothiophenyl group. The term “C₁-C₁₀ heterocycloalkylene

group” as used herein refers to a divalent group having the same structure as the C₁-C₁₀ heterocycloalkyl group.

[0418] The term “C₃-C₁₀ cycloalkenyl group” as used herein refers to a monovalent monocyclic group that has 3 to 10 carbon atoms and at least one carbon-carbon double bond in the ring thereof and does not have aromaticity, and non-limiting examples thereof include a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. The term “C₃-C₁₀ cycloalkenylene group” as used herein refers to a divalent group having the same structure as the C₃-C₁₀ cycloalkenyl group.

[0419] The term “C₁-C₁₀ heterocycloalkenyl group” as used herein refers to a monovalent monocyclic group that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, 1 to 10 carbon atoms, and at least one carbon-carbon double bond in its ring. Non-limiting examples of the C₁-C₁₀ heterocycloalkenyl group include a 4,5-dihydro-1,2,3,4-oxatriazolyl group, a 2,3-dihydrofuranyl group, and a 2,3-dihydrothiophenyl group. The term “C₁-C₁₀ heterocycloalkenylene group” as used herein refers to a divalent group having the same structure as the C₁-C₁₀ heterocycloalkenyl group.

[0420] The term “C₆-C₆₀ aryl group” as used herein refers to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms, and the term “C₆-C₆₀ arylene group” as used herein refers to a divalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms. Non-limiting examples of the C₆-C₆₀ aryl group include a phenyl group, a naphthyl group, an anthracenyl group, a phenanthrenyl group, a pyrenyl group, and a chrysenyl group. When the C₆-C₆₀ aryl group and the C₆-C₆₀ arylene group each include two or more rings, the rings may be fused to each other.

[0421] The term “C₁-C₆₀ heteroaryl group” as used herein refers to a monovalent group having a heterocyclic aromatic system that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, in addition to 1 to 60 carbon atoms. The term “C₁-C₆₀ heteroarylene group” as used herein refers to a divalent group having a heterocyclic aromatic system that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, in addition to 1 to 60 carbon atoms. Non-limiting examples of the C₁-C₆₀ heteroaryl group include a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, and an isoquinolinyl group. When the C₁-C₆₀ heteroaryl group and the C₁-C₆₀ heteroarylene group each include two or more rings, the rings may be fused to each other.

[0422] The term “C₆-C₆₀ aryloxy group” as used herein refers to —OA₁₀₂ (wherein A₁₀₂ is the C₆-C₆₀ aryl group), and a C₆-C₆₀ arylthio group used herein indicates —SA₁₀₃ (wherein A₁₀₃ is the C₆-C₆₀ aryl group).

[0423] The term “monovalent non-aromatic condensed polycyclic group” as used herein refers to a monovalent group (for example, having 8 to 60 carbon atoms) that has two or more rings condensed with each other, only carbon atoms as a ring-forming atom, and non-aromaticity in the entire molecular structure. A detailed example of the monovalent non-aromatic condensed polycyclic group is a fluorenyl group. The term “divalent non-aromatic condensed polycyclic group” as used herein refers to a divalent group having the same structure as the monovalent non-aromatic condensed polycyclic group.

[0424] The term “monovalent non-aromatic condensed heteropolycyclic group” as used herein refers to a monovalent group (for example, having 1 to 60 carbon atoms) that has two or more rings condensed to each other, has at least

one heteroatom selected from N, O, Si, P, and S, other than carbon atoms, as a ring-forming atom, and has non-aromaticity in the entire molecular structure. An example of the monovalent non-aromatic condensed heteropolycyclic group is a carbazolyl group. The term “divalent non-aromatic condensed heteropolycyclic group” as used herein refers to a divalent group having the same structure as the monovalent non-aromatic condensed heteropolycyclic group.

[0425] The term “C₅-C₆₀ carbocyclic group” as used herein refers to a monocyclic or polycyclic group having 5 to 60 carbon atoms in which a ring-forming atom is a carbon atom only. The C₅-C₆₀ carbocyclic group may be an aromatic carbocyclic group or a non-aromatic carbocyclic group. The C₅-C₆₀ carbocyclic group may be a ring, such as a benzene, a monovalent group, such as a phenyl group, or a divalent group, such as a phenylene group. In one or more embodiments, depending on the number of substituents connected to the C₅-C₆₀ carbocyclic group, the C₅-C₆₀ carbocyclic group may be a trivalent group or a quadrivalent group.

[0426] The term “C₁-C₆₀ heterocyclic group” as used herein refers to a group having the same structure as the C₁-C₆₀ carbocyclic group, except that as a ring-forming atom, at least one heteroatom selected from N, O, Si, P, and S is used in addition to carbon (the number of carbon atoms may be in a range of 1 to 60).

[0427] At least one of substituents of the substituted C₅-C₆₀ carbocyclic group, substituted C₁-C₆₀ heterocyclic group, substituted C₃-C₁₀ cycloalkylene group, substituted C₁-C₁₀ heterocycloalkylene group, substituted C₃-C₁₀ cycloalkenylene group, substituted C₁-C₁₀ heterocycloalkenylene group, substituted C₆-C₆₀ arylene group, substituted C₁-C₆₀ heteroarylene group, substituted divalent non-aromatic condensed polycyclic group, a substituted divalent non-aromatic condensed heteropolycyclic group, substituted C₁-C₆₀ alkyl group, substituted C₂-C₆₀ alkenyl group, substituted C₂-C₆₀ alkynyl group, substituted C₁-C₆₀ alkoxy group, substituted C₃-C₁₀ cycloalkyl group, substituted C₁-C₁₀ heterocycloalkyl group, substituted C₃-C₁₀ cycloalkenyl group, substituted C₁-C₁₀ heterocycloalkenyl group, substituted C₆-C₆₀ aryl group, substituted C₆-C₆₀ aryloxy group, substituted C₆-C₆₀ arylthio group, substituted C₁-C₆₀ heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from:

[0428] 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;

[0429] 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);

[0430] 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;

[0431] 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, 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

[0432] —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂),

[0433] 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.

[0434] 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 term “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.

[0435] The term “biphenyl group” as used therein refers to “a phenyl group substituted with a phenyl group.” In other words, a “biphenyl group” is a substituted phenyl group having a C₆-C₆₀ aryl group as a substituent.

[0436] The term “terphenyl group” as used herein refers to “a phenyl group substituted with a biphenyl group.” In other words, a “terphenyl group” is a substituted phenyl group having a C₆-C₆₀ aryl group substituted with a C₆-C₆₀ aryl group as a substituent.

[0437] * and *¹ used herein, unless defined otherwise, each refer to a binding site to a neighboring atom in a corresponding formula.

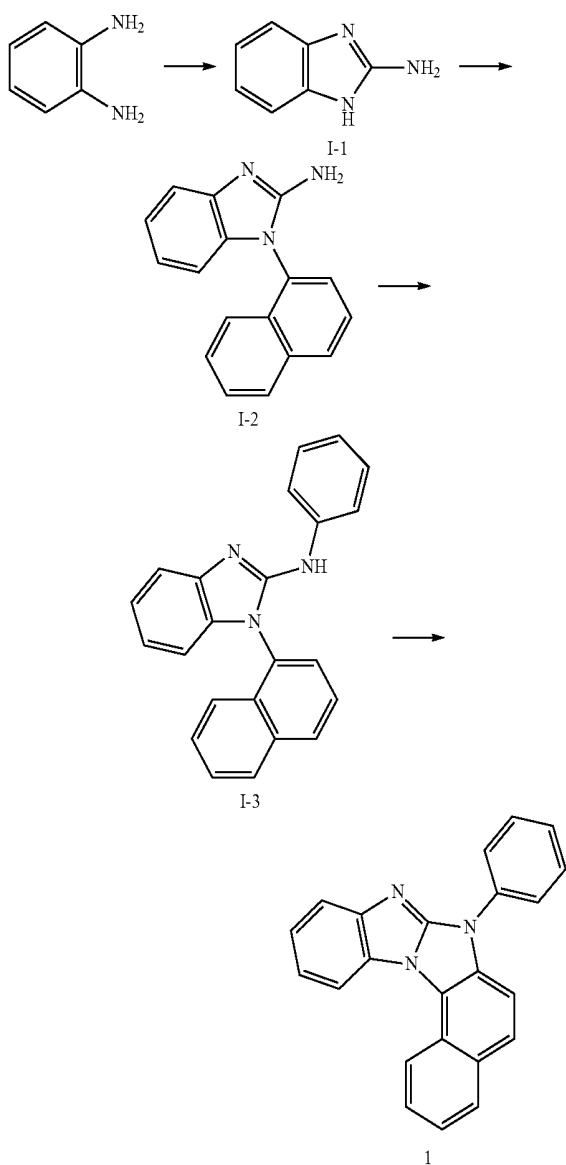
[0438] The following Examples and Comparative Examples are provided in order to highlight characteristics of one or more embodiments, but it will be understood that the Examples and Comparative Examples are not to be construed as limiting the scope of the embodiments, nor are the Comparative Examples to be construed as being outside the scope of the embodiments. Further, it will be understood that the embodiments are not limited to the particular details described in the Examples and Comparative Examples. The wording “B was used instead of A” used in describing Synthesis Examples indicates that an identical molar equivalent of B was used in place of A.

EXAMPLE

Synthesis Example 1

Synthesis of Compound 1

[0439]



Synthesis of Intermediate I-1

[0440] 1.08 g (10 mmol) of o-phenylene diamine and 1.06 g (10 mmol) of cyanogen bromide were dissolved in 100 mL of MeOH and were then stirred at room temperature for 24 hours. An ammonia solution was added thereto, and an extraction process was performed thereon three times by using 60 mL of ethyl acetate. An organic layer collected therefrom was dried by using MgSO_4 and a solvent was removed therefrom by evaporation. The residue obtained therefrom was separated and purified by silica gel column chromatography, thereby completing the preparation of 1.06 g (80%) of Intermediate I-1. The obtained compound was identified by LC-MS.

[0441] $\text{C}_7\text{H}_7\text{N}_3$: M^+ 133.06

Synthesis of Intermediate I-2

[0442] 1.33 g (10 mmol) of Intermediate I-1, 2.23 g (10 mmol) of 1-bromonaphthalene, 2.89 g (1.5 equiv) of CsCO_3 , 20 mg (10 mol %) of CuI , and 200 mg (15 mol %) of 8-quinolinol were dissolved in 100 mL of t-BuOH and were then stirred at a temperature of 90° C. for 18 hours. The obtained result was cooled to room temperature, and an extraction process was performed thereon three times by using 60 mL of ethyl acetate. An organic layer obtained therefrom was dried by using MgSO_4 and a solvent was removed therefrom by evaporation. The residue obtained therefrom was separation-purified by silica gel column chromatography, thereby completing the preparation of 2.02 g (78%) Intermediate I-2. The obtained compound was identified by LC-MS.

[0443] $\text{C}_{17}\text{H}_{13}\text{N}_3$: M^+ 259.10

Synthesis of Intermediate I-3

[0444] 2.59 g (10 mmol) of Intermediate I-2, 1.73 g (11 mmol) of bromobenzene, 0.1 mol % of $\text{Pd}_2(\text{dba})_3$, and 3.18 g (1.5 equiv) of K_3PO_4 were dissolved in 100 mL of t-BuOH and were then stirred at a temperature of 120° C. for 5 hours. The obtained result was cooled to room temperature, and an extraction process was performed thereon three times by using 60 mL of ethyl acetate. An organic layer collected therefrom was dried by using MgSO_4 and a solvent was removed therefrom by evaporation. The residue obtained therefrom was separation-purified by silica gel column chromatography, thereby completing the preparation of 2.58 g (77%) of Intermediate I-3. The obtained compound was identified by LC-MS.

[0445] $\text{C}_{23}\text{H}_{17}\text{N}_3$: M^+ 335.15

Synthesis of Compound 1

[0446] 3.35 g (10 mmol) of Intermediate I-3, $\text{Cu}(\text{OAc})_2$, PPh_3 , 1,10-phenanthroline, and NaOAc were dissolved and stirred at a temperature of 80° C. for 12 hours. The obtained residue was cooled to room temperature, and an extraction process was performed thereon three times by using 30 mL of water and 30 mL of ethyl acetate. An organic layer obtained therefrom was dried by using magnesium sulfate and a solvent was removed therefrom by evaporation. Then, the residue obtained therefrom was separation-purified by silica gel column chromatography, thereby completing the preparation of 2.33 g (70%) of Compound 1. The obtained compound was identified by MS/FAB and ^1H NMR.

Synthesis Example 2

Synthesis of Compound 4

[0447] 2.09 g (63%) of Compound 4 was obtained in the same manner as in Synthesis of Compound 1, except that 3-bromopyridine was used instead of bromobenzene in synthesizing Intermediate I-3. The obtained compound was identified by MS/FAB and ¹H NMR.

Synthesis Example 3

Synthesis of Compound 12

[0448] 2.14 g (58%) of Compound 12 was obtained in the same manner as in Synthesis of Compound 1, except that 3-bromo-2,6-difluoropyridine was used instead of bromobenzene in synthesizing Intermediate I-3. The obtained compound was identified by MS/FAB and ¹H NMR.

Synthesis Example 4

Synthesis of Compound 15

[0449] 4.19 g (70%) of Compound 15 was obtained in the same manner as in Synthesis of Compound 1, except that 6-(3-bromophenyl)dinaphtho[2,1-b:1',2'-d]furan was used instead of bromobenzene in synthesizing Intermediate I-3. The obtained compound was identified by MS/FAB and ¹H NMR.

Synthesis Example 5

Synthesis of Compound 30

[0450] 4.19 g (70%) of Compound 30 was obtained in the same manner as in Synthesis of Compound 1, except that 3-(3-bromophenyl)-2,6-difluoropyridine was used instead of bromobenzene in synthesizing Intermediate I-3. The obtained compound was identified by MS/FAB and ¹H NMR.

Synthesis Example 6

Synthesis of Compound 31

[0451] 2.37 g (71%) of Compound 31 was obtained in the same manner as in Synthesis of Compound 1, except that 5-bromoquinoline was used instead of 1-bromonaphthalene in synthesizing Intermediate I-2. The obtained compound was identified by MS/FAB and ¹H NMR.

Synthesis Example 7

Synthesis of Compound 37

[0452] 2.24 g (68%) Compound 37 was obtained in the same manner as in Synthesis of Compound 1, except that 4-bromoquinoline was used instead of 1-bromonaphthalene in synthesizing Intermediate I-2. The obtained compound was identified by MS/FAB and ¹H NMR.

Synthesis Example 8

Synthesis of Compound 40

[0453] 3.67 g (64%) of Compound 2 was obtained in the same manner as in Synthesis of Compound 1, except that 4-bromodibenzo[b,d]furan was used instead of 1-bromonaphthalene in synthesizing Intermediate I-2, and (3-bromophenyl)diphenylphosphine oxide was used instead of bromobenzene in synthesizing Intermediate I-3. The obtained compound was identified by MS/FAB and ¹H NMR.

Synthesis Example 9

Synthesis of Compound 41

[0454] 3.17 g (71%) of Compound 41 was obtained in the same as in Synthesis of Compound 1, except that 4-bromoquinoline was used instead of 1-bromonaphthalene in synthesizing Intermediate I-2, and 3-(4-bromophenyl)-2,6-difluoropyridine was used instead of bromobenzene in synthesizing Intermediate I-3. The obtained compound was identified by MS/FAB and ¹H NMR.

Synthesis Example 10

Synthesis of Compound 50

[0455] 3.60 g (61%) of Compound 50 was obtained in the same manner as in Synthesis of Compound 1, except that 4-bromodibenzo[b,d]furan was used instead of 1-bromonaphthalene in synthesizing Intermediate I-2, and 7-(6-bromopyridin-2-yl)-9,9-dimethyl-9H-fluorene-2-carbonitrile was used instead of bromobenzene in synthesizing Intermediate I-3. The obtained compound was identified by MS/FAB and ¹H NMR.

[0456] ¹H NMR and MS/FAB of Compounds synthesized in Synthesis Examples 1 to 10 are shown in Table 1 below.

[0457] Methods of synthesizing compounds other than Compounds shown in Table 1 are recognizable by one of ordinary skill in the art by referring to the synthesis paths and source materials described above.

TABLE 1

Compound	¹ H NMR (CDCl ₃ , 500 MHz)	HR-EIMS	
		found	calc.
1	δ = 8.32-8.38 (m, 1H), 8.08-7.97 (m, 2H), 7.60-7.35 (m, 11H)	333.15	333.13
4	δ = 8.66-8.60 (m, 2H), 8.35-8.24 (m, 2H), 8.06-8.02 (m, 2H), 7.94-7.92 (d, 1H), 7.53-7.45 (m, 6H), 7.30-7.35 (m, 1H)	334.14	334.12
12	δ = 8.35-8.31 (d, 1H), 8.06-8.00 (m, 4H), 7.55-7.33 (m, 6H), 7.94-7.92 (d, 1H), 7.53-7.45 (m, 6H), 6.94-6.92 (d, 1H)	370.11	370.10
15	δ = 8.84-8.82 (m, 2H), 8.45-8.35 (m, 2H), 8.06-8.01 (m, 2H), 7.94-7.88 (m, 5H), 7.73-7.71 (m, 2H), 7.62-7.45 (m, 10H), 7.35-7.29 (d, 1H)	599.21	599.20

TABLE 1-continued

Compound	¹ H NMR (CDCl ₃ , 500 MHz)	HR-EIMS	
		found	calc.
30	δ = 8.64-8.56 (m, 2H), 8.42-8.38 (m, 3H), 7.79 (s, 1H), 7.70-7.69 (d, 2H), 7.53-7.51 (m, 3H), 7.50-7.35 (m, 6H), 6.68 (s, 1H)	496.17	496.15
31	δ = 9.29 (s, 1H), 8.24 (s, 1H), 7.95 (s, 1H), 7.77 (s, 1H), 7.63-7.52 (m, 6H), 7.48-7.40 (m, 4H)	334.11	334.12
37	δ = 9.18 (s, 1H), 8.34 (s, 1H), 8.23 (s, 1H), 7.82 (s, 1H), 7.69-7.60 (m, 6H), 7.47-7.35 (m, 4H)	334.11	334.12
40	δ = 8.15-8.17 (d, 1H), 7.96-7.98 (d, 1H), 7.87-7.84 (d, 1H), 7.82-7.80 (m, 1H), 7.73-7.69 (m, 6H), 7.63-7.55 (m, 3H), 7.49-7.38 (m, 11H)	573.17	573.16
41	δ = 9.24 (s, 1H), 8.37-8.34 (m, 2H), 8.24-8.22 (d, 1H), 7.84-7.80 (m, 1H), 7.68-7.67 (m, 3H), 7.60-7.58 (d, 1H), 7.50-7.45 (m, 4H), 7.37-7.30 (m, 1H), 6.76-6.73 (m, 12H)	447.15	447.13
50	δ = 8.33-8.31 (d, 1H), 8.19-8.16 (d, 2H), 7.97-7.95 (m, 3H), 7.88-7.78 (m, 5H), 7.66-7.58 (m, 3H), 7.50-7.38 (m, 6H), 1.65 (s, 6H)	591.20	591.21

Example 1

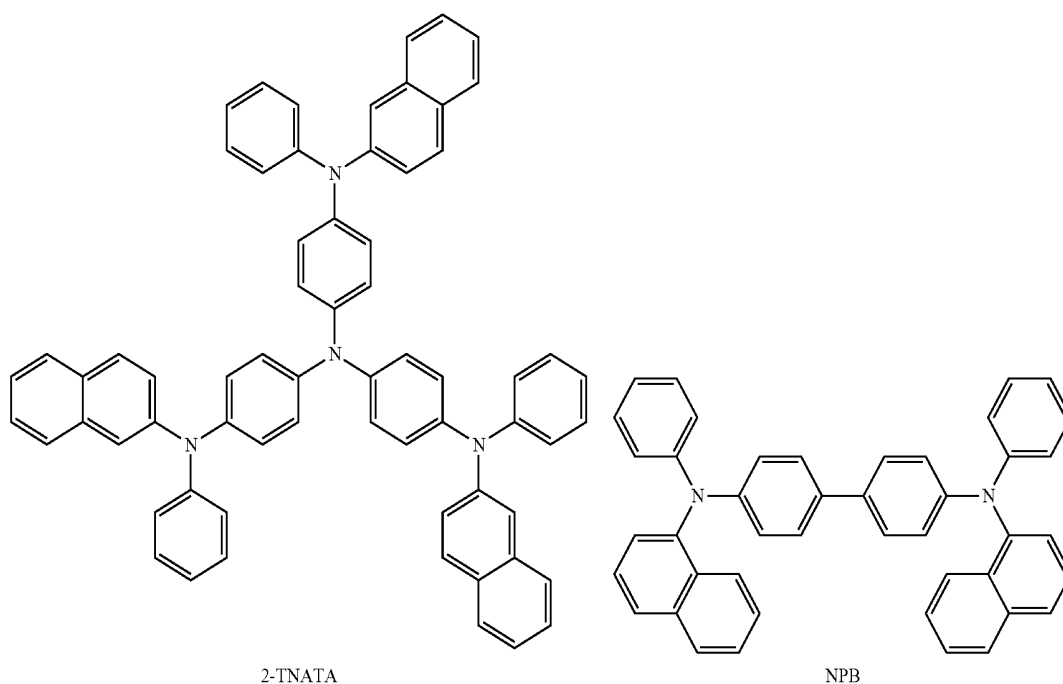
[0458] An anode was prepared by cutting an ITO glass substrate (manufactured by Corning), on which an ITO layer was deposited to a thickness of 15 Ω/cm² (1,200 Å), to a size of 50 mm×50 mm×0.7 mm, ultrasonically cleaning the ITO glass substrate (anode) using isopropyl alcohol and pure water each for 5 minutes, and then, exposing the ITO glass substrate (anode) to UV irradiation for 30 minutes and ozone to clean the ITO glass substrate. Then, the ITO glass substrate (anode) was loaded into a vacuum deposition apparatus.

[0459] 2-TNATA was vacuum-deposited on the ITO glass substrate (anode) to form a hole injection layer having a

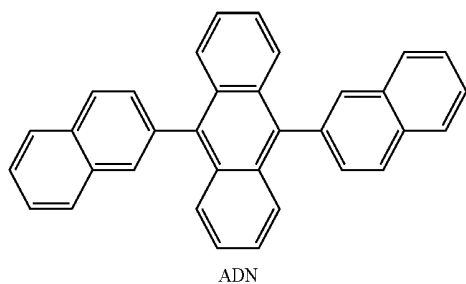
thickness of 600 Å, and NPB was vacuum-deposited on the hole injection layer to form a hole transport layer having a thickness of 300 Å, thereby forming a hole transport region.

[0460] AND (host) and DPAVB_i (dopant) were co-deposited on the hole transport layer at a weight ratio of 98:2 to form an emission layer having a thickness of 300 Å.

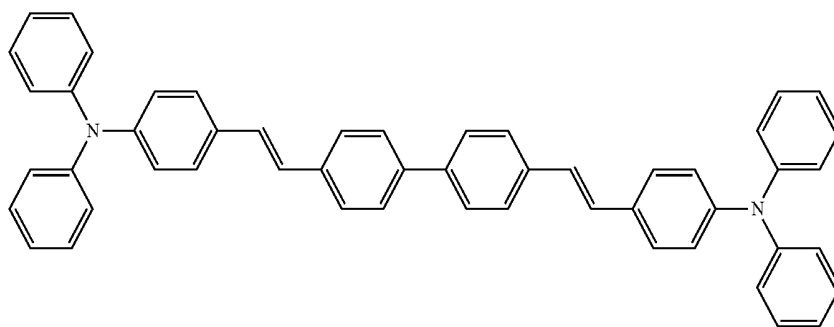
[0461] Then, Compound 1 was deposited on the emission layer to form an electron transport layer having a thickness of 300 Å, LiF was deposited on the electron transport layer to form an electron injection layer having a thickness of 10 Å, and Al was vacuum-deposited on the electron injection layer to form a cathode having a thickness of 3,000 Å, thereby completing the manufacture of an organic light-emitting device.



-continued



ADN



DPAVBi

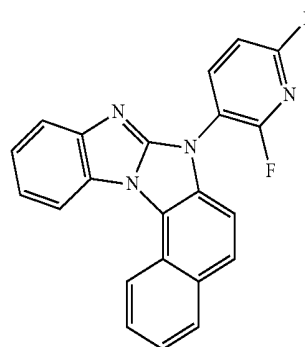
Examples 2 to 10 and Comparative Examples 1 to 4

4

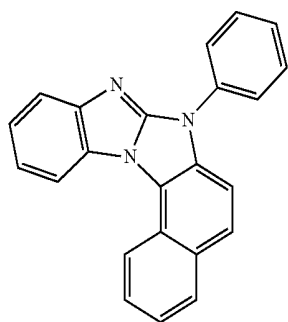
[0462] Organic light-emitting devices of Examples 2 to 10 and Comparative Examples 1 to 4 were manufactured in the same manner as in Example 1, except that Compounds shown in Table 2 were each used in forming an electron transport layer.

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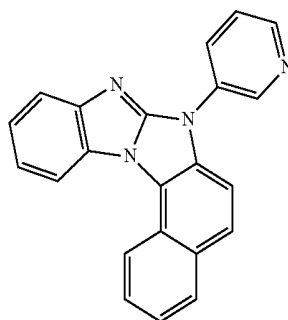
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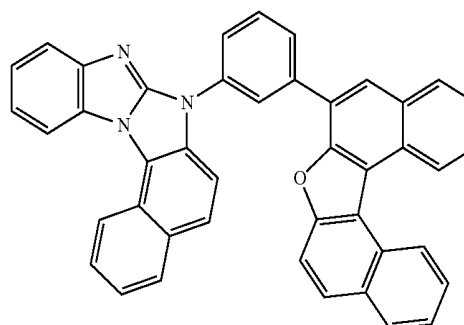
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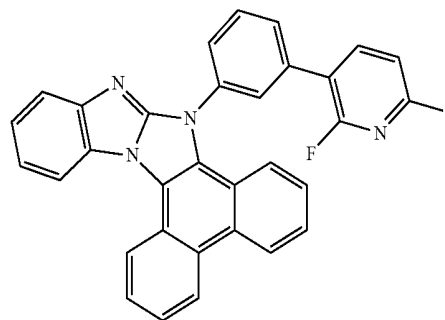
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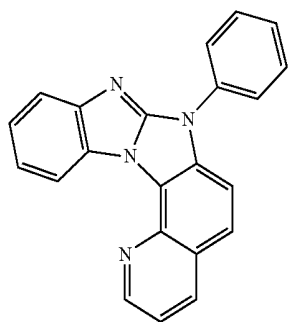
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30

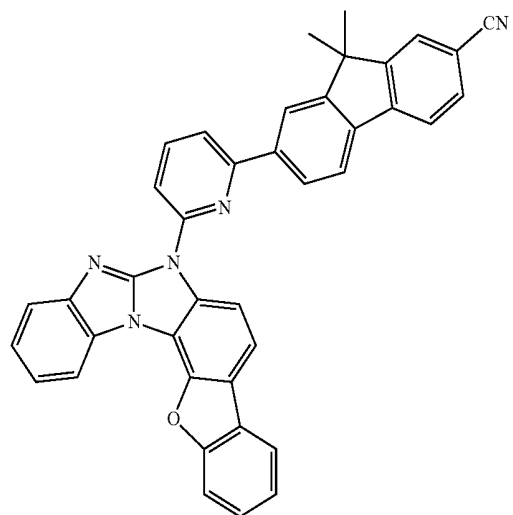


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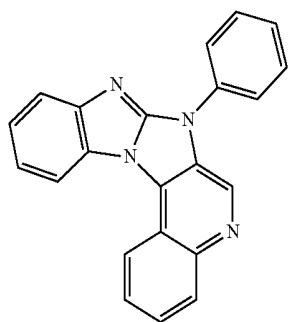
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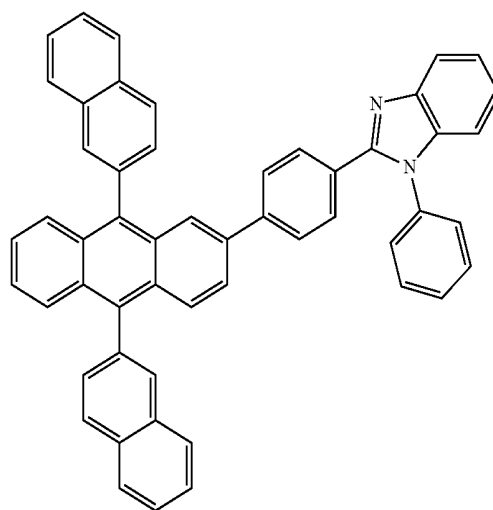
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50

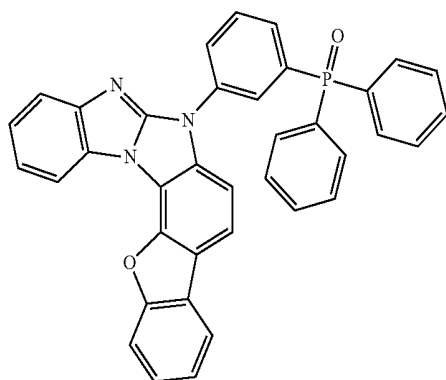


40

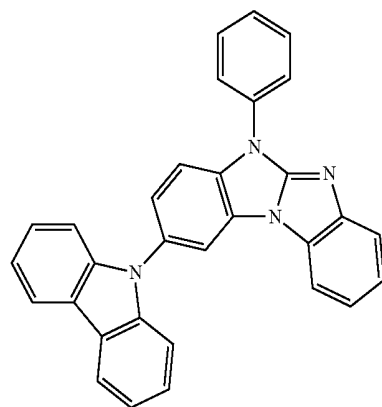
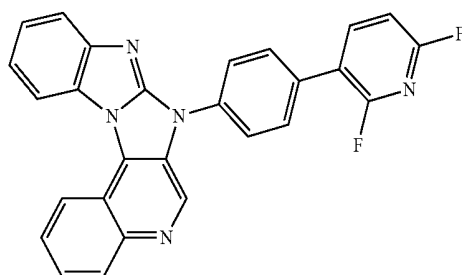
A



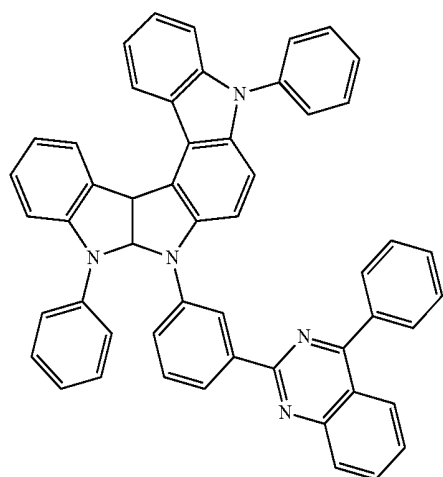
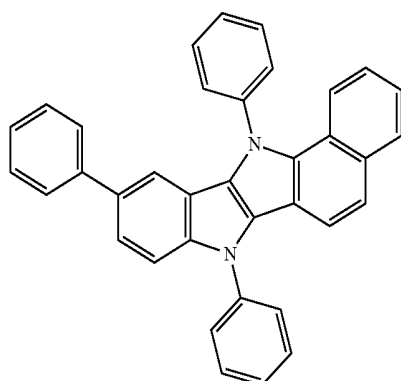
B



41



-continued



C

may have a low driving voltage, high luminance, high efficiency, and a long lifespan.

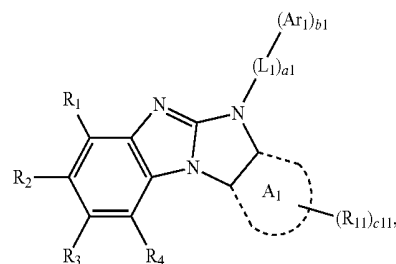
[0465] Example embodiments have been disclosed herein, and although specific terms are employed, they are used and are to be interpreted in a generic and descriptive sense only and not for purpose of limitation. In some instances, as would be apparent to one of ordinary skill in the art as of the filing of the present application, features, characteristics, and/or elements described in connection with a particular embodiment may be used singly or in combination with features, characteristics, and/or elements described in connection with other embodiments unless otherwise specifically indicated. Accordingly, it will be understood by those of skill in the art that various changes in form and details may be made without departing from the spirit and scope of the present invention as set forth in the following claims.

D

What is claimed is:

1. A heterocyclic compound represented by Formula 1:

<Formula 1>



wherein, in Formula 1,

ring L_1 is a C_{10} - C_{60} carbocyclic group or a C_6 - C_{60} heterocyclic group,

TABLE 2

	Material for electron transport layer	Driving voltage (V)	Current density (mA/cm ²)	Luminance (cd/m ²)	Efficiency (cd/A)	Emission color	Half lifespan (hr @ 100 mA/cm ²)
Example 1	Compound 1	4.33	50	3,025	6.05	Blue	242 hr
Example 2	Compound 4	4.21	50	3,115	6.23	Blue	265 hr
Example 3	Compound 12	4.03	50	3,285	6.57	Blue	223 hr
Example 4	Compound 15	4.19	50	3,165	6.33	Blue	277 hr
Example 5	Compound 30	4.03	50	3,330	6.66	Blue	215 hr
Example 6	Compound 31	4.14	50	3,205	6.41	Blue	223 hr
Example 7	Compound 37	4.11	50	3,155	6.31	Blue	285 hr
Example 8	Compound 40	4.07	50	3,375	6.75	Blue	220 hr
Example 9	Compound 41	4.02	50	3,315	6.63	Blue	205 hr
Example 10	Compound 50	4.15	50	3,070	6.14	Blue	210 hr
Comparative Example 1	A	4.50	50	2,325	4.65	Blue	70 hr
Comparative Example 2	B	4.39	50	2,685	5.37	Blue	150 hr
Comparative Example 3	C	4.94	50	2,275	4.55	Blue	57 hr
Comparative Example 4	D	4.59	50	2,425	4.85	Blue	83 hr

[0463] Referring to Table 2, it can be seen that the organic light-emitting devices of Examples 1 to 10 had a high driving voltage, high brightness, high efficiency, and a long half lifespan, compared to the devices of Comparative Examples 1 to 4.

[0464] According to one or more embodiments, an organic light-emitting device including the heterocyclic compound

L_1 is selected from a substituted or unsubstituted C_3 - C_{60} carbocyclic group, a substituted or unsubstituted C_1 - C_{60} heterocyclic group, $^*S(=O)^*$, $^*S(=O)_2^*$, $^*P(=O)(Q_4)^*$, and $^*P(=S)(Q_4)^*$,

a_1 is an integer selected from 0 to 5, wherein, when a_1 is two or more, two or more $L_1(s)$ are identical to or different from each other,

Ar₁ is selected from a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —S(=O)(Q₁), —S(=O)₂(Q₁), —P(=O)(Q₁)(Q₂), and —P(=S)(Q₁)(Q₂),

b1 is an integer selected from 1 to 5, wherein, when b1 is two or more, two or more Ar₁(s) are identical to or different from each other,

R₁ to R₄ and R₁₁ are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₂-C₆₀ alkenyl group, a substituted or unsubstituted C₂-C₆₀ alkynyl group, a substituted or unsubstituted C₁-C₆₀ alkoxy group, a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(Q₁)(Q₂)(Q₃), —N(Q₁)(Q₂), —B(Q₁)(Q₂), —C(=O)(Q₁), —S(=O)₂(Q₁), and —P(=O)(Q₁)(Q₂),

c11 is an integer selected from 0 to 6, wherein, when c11 is two or more, two or more R₁₁(s) are identical to or different from each other,

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

deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group;

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

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 amino group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, a terphenyl group, —Si(Q₂₁)(Q₂₂)(Q₂₃), —N(Q₂₁)(Q₂₂), —B(Q₂₁)(Q₂₂), —C(=O)(Q₂₁), —S(=O)₂(Q₂₁), and —P(=O)(Q₂₁)(Q₂₂); and

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

Q₁ to Q₄, Q₁₁ to Q₁₃, Q₂₁ to Q₂₃, and Q₃₁ to Q₃₃ are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, and

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

2. The heterocyclic compound as claimed in claim 1, wherein:

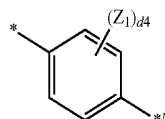
ring A₁ is a C₁₀-C₆₀ carbocyclic group with two or more rings condensed with each other, or a C₆-C₆₀ heterocyclic group with two or more rings condensed with each other.

3. The heterocyclic compound as claimed in claim 1, wherein:

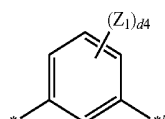
ring A₁ is a naphthalene, a fluorene, a benzofluorene, a phenanthrene, an anthracene, a quinoline, an isoquinoline, a benzoquinoline, a carbazole, a dibenzofuran, a dibenzothiophene, or a benzocarbazole.

4. The heterocyclic compound as claimed in claim 1, wherein:

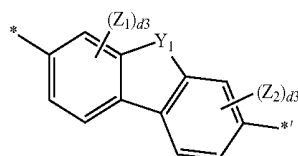
L₁ is selected from groups represented by Formulae 3-1 to 3-51:



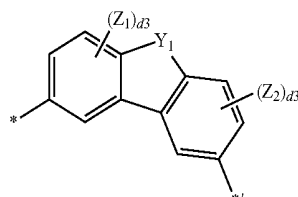
Formula 3-1



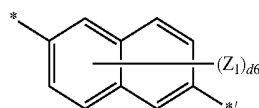
Formula 3-2



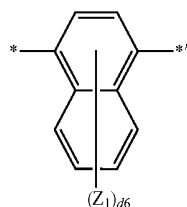
Formula 3-3



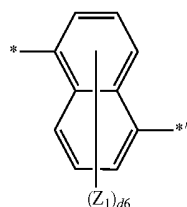
Formula 3-4



Formula 3-5



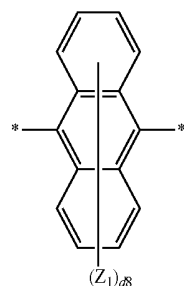
Formula 3-6



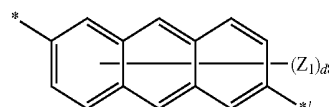
Formula 3-7

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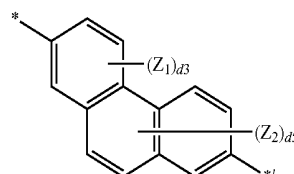
Formula 3-8



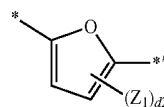
Formula 3-9



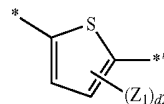
Formula 3-10



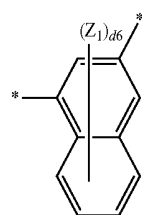
Formula 3-11



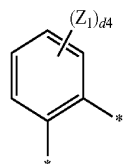
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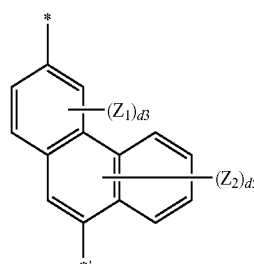
Formula 3-13



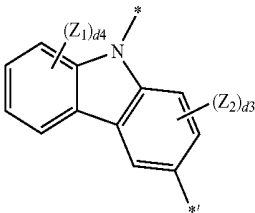
Formula 3-14



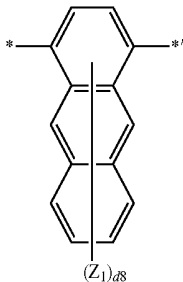
Formula 3-15



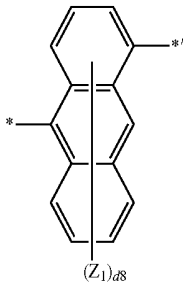
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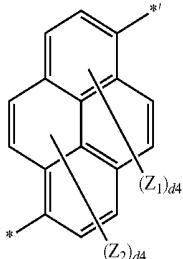
Formula 3-16



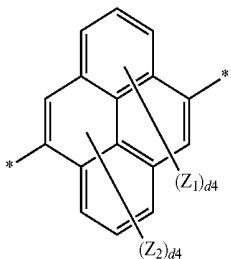
Formula 3-17



Formula 3-18

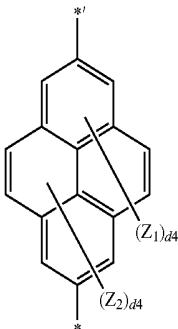


Formula 3-19

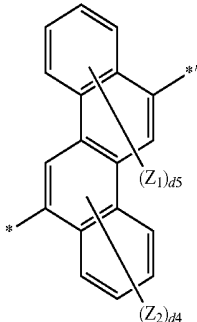


Formula 3-20

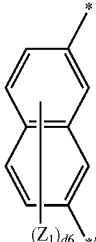
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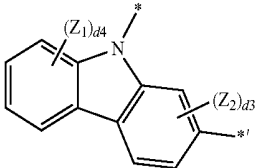
Formula 3-21



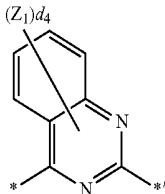
Formula 3-22



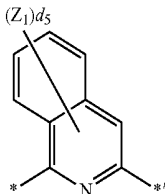
Formula 3-23



Formula 3-24

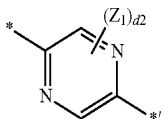
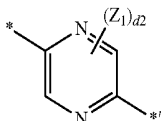
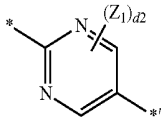
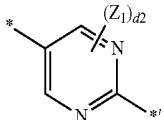
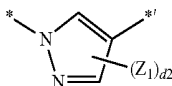
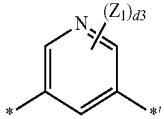
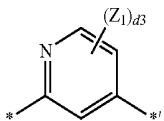
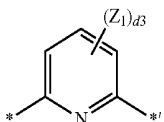
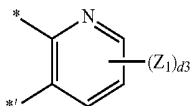
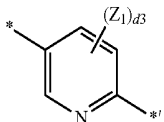
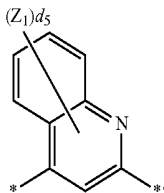


Formula 3-25



Formula 3-26

-continued



Formula 3-27

Formula 3-28

Formula 3-29

Formula 3-30

Formula 3-31

Formula 3-32

Formula 3-33

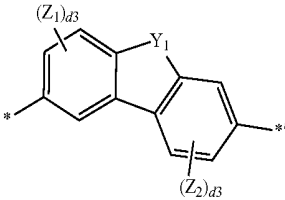
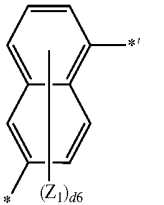
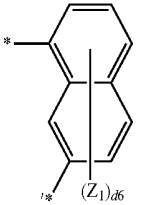
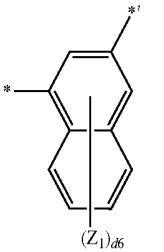
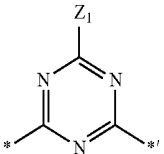
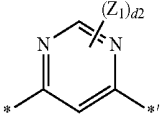
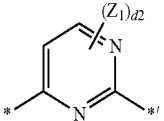
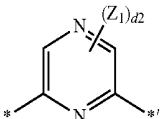
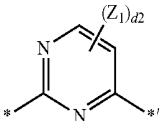
Formula 3-34

Formula 3-35

Formula 3-36

Formula 3-37

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Formula 3-38

Formula 3-39

Formula 3-40

Formula 3-41

Formula 3-42

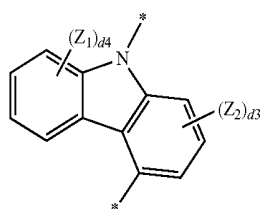
Formula 3-43

Formula 3-44

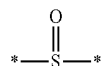
Formula 3-45

Formula 3-46

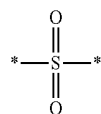
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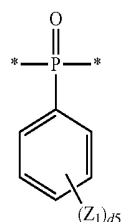
Formula 3-47



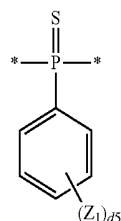
Formula 3-48



Formula 3-49



Formula 3-50



Formula 3-51

wherein, in Formulae 3-1 to 3-51,

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

Z_1 to Z_4 are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkenyl group, a C_1 - C_{20} alkynyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, — $Si(Q_{31})(Q_{32})(Q_{33})$, — $N(Q_{31})(Q_{32})$, — $B(Q_{31})(Q_{32})$, — $C(=O)(Q_{31})$, — $S(=O)_2(Q_{31})$, and — $P(=O)(Q_{31})(Q_{32})$,

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

d_2 is 1 or 2,

d_3 is an integer selected from 1 to 3,

d_4 is an integer selected from 1 to 4,

d_5 is an integer selected from 1 to 5,

d_6 is an integer selected from 1 to 6,

d_8 is an integer selected from 1 to 8, and

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

5. The heterocyclic compound as claimed in claim 1, wherein:

L_1 is selected from:

a benzene group, a fluorene group, an anthracene group, a pyridine group, a triazine group, and a carbazole group;

a benzene group, a fluorene group, an anthracene group, a pyridine group, a triazine group, and a carbazole group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, — $Si(Q_{31})(Q_{32})(Q_{33})$, — $N(Q_{31})(Q_{32})$, and — $B(Q_{31})(Q_{32})$; and

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

Q_4 and Q_{31} to Q_{33} are each independently selected from a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, and

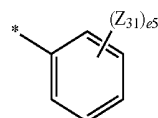
* and *' each indicate a binding site to a neighboring atom.

6. The heterocyclic compound as claimed in claim 1, wherein:

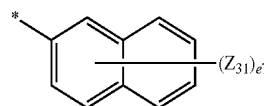
a_1 is an integer selected from 0 to 3.

7. The heterocyclic compound as claimed in claim 1, wherein:

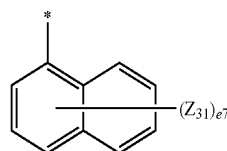
Ar_1 is selected from groups represented by Formulae 5-1 to 5-29, — $S(=O)(Q_1)$, — $S(=O)_2(Q_1)$, — $P(=O)(Q_1)(Q_2)$, and — $P(=S)(Q_1)(Q_2)$:



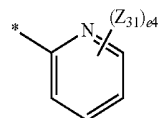
Formula 5-1



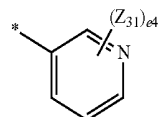
Formula 5-2



Formula 5-3

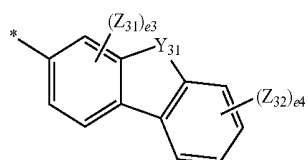
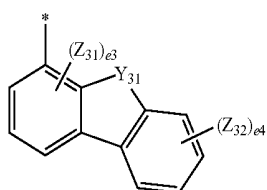
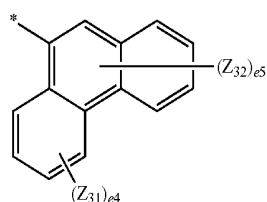
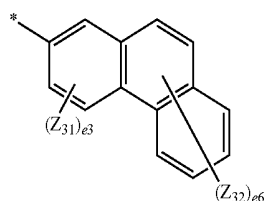
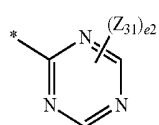
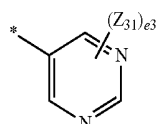
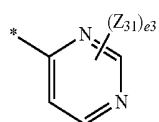
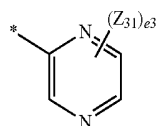
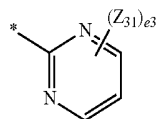
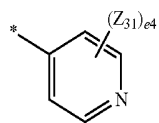


Formula 5-4



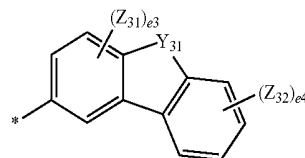
Formula 5-5

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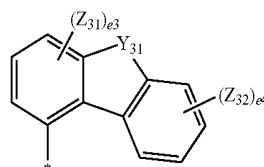
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Formula 5-6



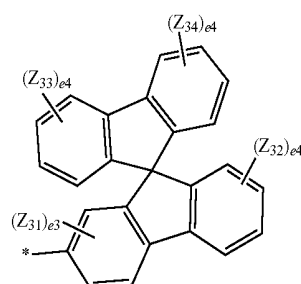
Formula 5-7

Formula 5-8



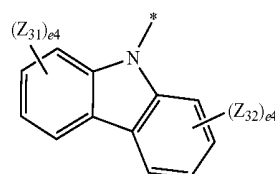
Formula 5-9

Formula 5-10



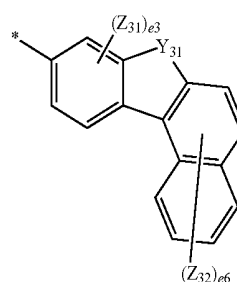
Formula 5-11

Formula 5-12

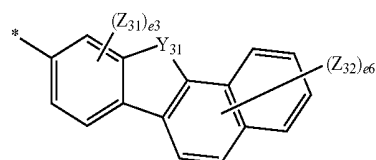
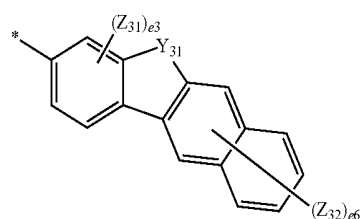


Formula 5-13

Formula 5-14



Formula 5-15



Formula 5-16

Formula 5-17

Formula 5-18

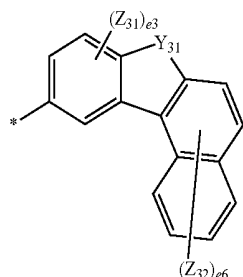
Formula 5-19

Formula 5-20

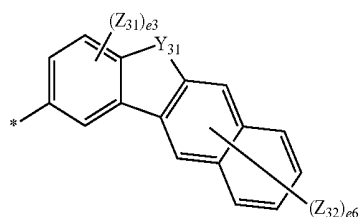
Formula 5-21

Formula 5-22

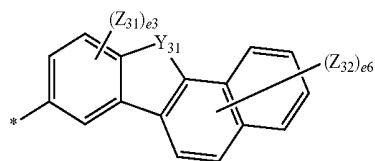
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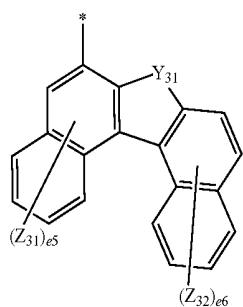
Formula 5-23



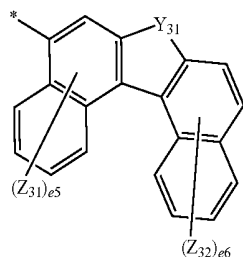
Formula 5-24



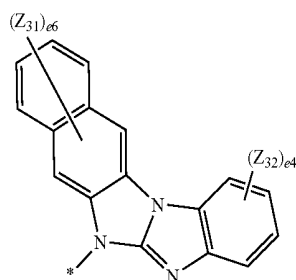
Formula 5-25



Formula 5-26

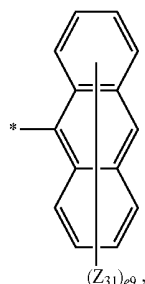


Formula 5-27



Formula 5-28

-continued



Formula 5-29

wherein, in Formulae 5-1 to 5-29.

Y_{31} is O, S, C(Z_{35})(Z_{36}), N(Z_{35}), or Si(Z_{35})(Z_{36}).

Z_{31} to Z_{36} are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkenyl group, a C_1 - C_{20} alkynyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, —Si(Q_{31})(Q_{32})(Q_{33}), —N(Q_{31})(Q_{32}), —B(Q_{31})(Q_{32}), —C(=O)(Q_{31}), —S(=O)₂(Q_{31}), and —P(=O)(Q_{31})(Q_{32}),

wherein Q_1 , Q_2 , and Q_{31} to Q_{33} are each independently selected from a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group,

e_2 is 1 or 2,

e_3 is an integer selected from 1 to 3,

e_4 is an integer selected from 1 to 4,

e_5 is an integer selected from 1 to 5,

e_6 is an integer selected from 1 to 6,

e_7 is an integer selected from 1 to 7,

e_9 is an integer selected from 1 to 9, and

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

8. The heterocyclic compound as claimed in claim 1, wherein:

Ar_1 is selected from:

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, a pyridinyl group, a dinaphthofuranyl group, and a benzoimidazonaphthoimidazolyl group;

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, a pyridinyl group, a dinaphthofuranyl group, and a benzoimidazonaphthoimidazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a

hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, —N(Q₃₁)(Q₃₂), and —Si(Q₃₁)(Q₃₂)(Q₃₃); and
 —S(=O)(Q₁), —S(=O)₂(Q₁), —P(=O)(Q₁)(Q₂), and —P(=S)(Q₁)(Q₂),

wherein Q₁, Q₂, and Q₃₁ to Q₃₃ are each independently selected from a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

9. The heterocyclic compound as claimed in claim 1, wherein:

b1 is 1 or 2.

10. The heterocyclic compound as claimed in claim 1, wherein:

R₁ to R₄ are each independently selected from:

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

a 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, and a nitro group;

a phenyl group, a biphenyl group, a terphenyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyridinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

a phenyl group, a biphenyl group, a terphenyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyridinyl 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 phenyl group, a biphenyl group, a terphenyl group, —N(Q₃₁)(Q₃₂), and —Si(Q₃₁)(Q₃₂)(Q₃₃); and

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

R₁₁ is selected from:

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

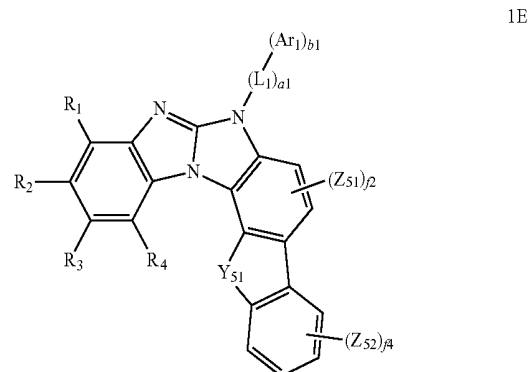
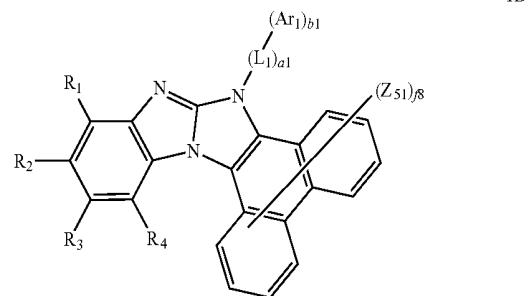
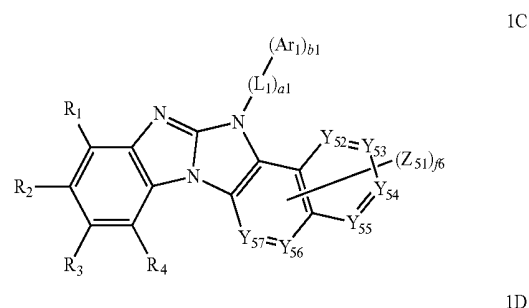
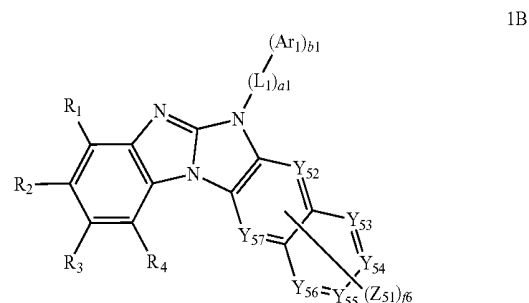
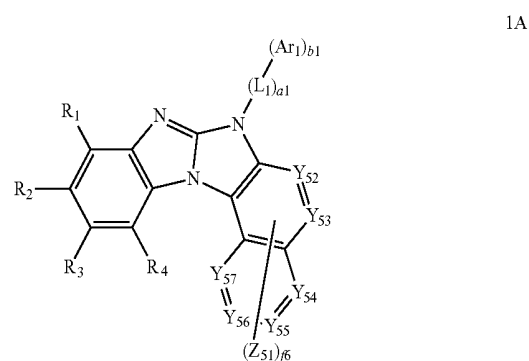
a C₁-C₂₀ alkyl group and a C₁-C₂₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, and a nitro group; and

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

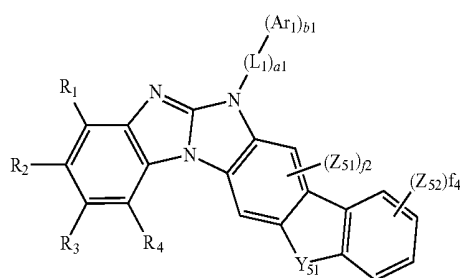
wherein Q₁ to Q₃ and Q₃₁ to Q₃₃ are each independently selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

11. The heterocyclic compound as claimed in claim 1, wherein:

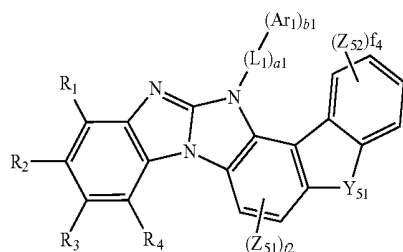
the compound represented by Formula 1 is represented by one selected from Formulae 1A to 1J:



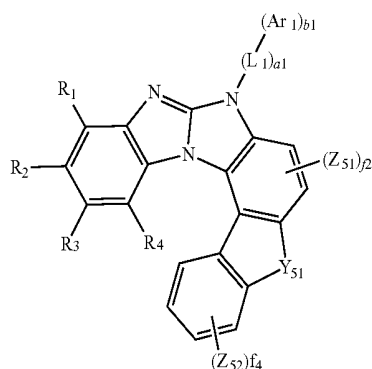
-continued



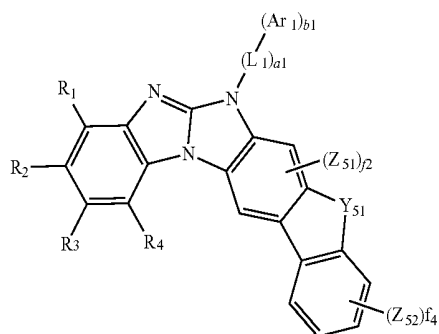
1F



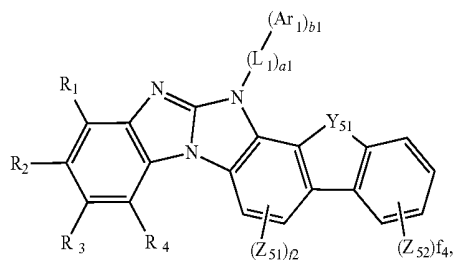
1G



1H



1I



1J

wherein, in Formulae 1A to 1J,

L_1 , a_1 , Ar_1 , b_1 , and R_1 to R_4 are the same as described in claim 1,

Y_{51} is O, S, $C(Z_{53})(Z_{54})$, $N(Z_{53})$, or $Si(Z_{53})(Z_{54})$,

Y_{52} to Y_{57} are each independently $C(Z_{55})$ or N,
 Z_{51} to Z_{55} 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, and a naphthyl group,

f_2 is 1 or 2,

f_4 is an integer selected from 1 to 4,

f_6 is an integer selected from 1 to 6, and

f_8 is an integer selected from 1 to 8.

12. The heterocyclic compound as claimed in claim 11, wherein,

in Formulae 1A and 1J,

L_1 is selected from:

a benzene group, a fluorene group, an anthracene group, a pyridine group, a triazine group, and a carbazole group;

a benzene group, a fluorene group, an anthracene group, a pyridine group, a triazine group, and a carbazole group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, — $Si(Q_{31})(Q_{32})(Q_{33})$, — $N(Q_{31})(Q_{32})$, and — $B(Q_{31})(Q_{32})$; and

— $S(=O)$ —, *— $S(=O)_2$ —*, *— $P(=O)(Q_4)$ —*, and *— $P(=S)(Q_4)$ —*,

a_1 is an integer selected from 0 to 3,

Ar_1 is selected from:

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, a pyridinyl group, dinaphthofuranyl group, and a benzoimidazonaphthoimidazolyl group;

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, a pyridinyl group, a dinaphthofuranyl group, and a benzoimidazonaphthoimidazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, — $N(Q_{31})(Q_{32})$, and — $Si(Q_{31})(Q_{32})(Q_{33})$; and

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

b_1 is 1 or 2,

R_1 to R_4 are each independently selected from:

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

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

a phenyl group, a biphenyl group, a terphenyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyridinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

a phenyl group, a biphenyl group, a terphenyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyridinyl group, a carbazolyl group, a diben-

zofuranyl 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 phenyl group, a biphenyl group, a terphenyl group, —N(Q₃₁)(Q₃₂), and —Si(Q₃₁)(Q₃₂)(Q₃₃); and

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

wherein Q₁ to Q₄ and Q₃₁ to Q₃₃ are each independently selected from a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

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,
wherein the organic layer comprises at least one of the heterocyclic compounds as claimed in claim 1.

14. The organic light-emitting device as claimed in claim 13, wherein
the first electrode is an anode,
the second electrode is a cathode, and
the organic layer further comprises a hole transport region between the first electrode and the emission layer and an electron transport region between the emission layer and the second electrode,
the hole transport region comprises a hole injection layer, a hole transport layer, an emission auxiliary layer, an electron blocking layer, or any combination thereof, and

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

15. The organic light-emitting device as claimed in claim 14, wherein:

the electron transport region comprises the at least one of the heterocyclic compounds.

16. The organic light-emitting device as claimed in claim 14, wherein:

the electron transport region comprises an electron transport layer, and

the electron transport layer comprises the at least one of the heterocyclic compounds.

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

the electron transport layer further comprises a metal-containing material.

18. The organic light-emitting device as claimed in claim 17, wherein the metal-containing material comprises a Li complex.

19. The organic light-emitting device as claimed in claim 14, wherein

the hole transport region comprises a p-dopant, and
a lowest unoccupied molecular orbital (LUMO) level of the p-dopant is about -3.5 eV or less.

20. The organic light-emitting device as claimed in claim 19, wherein

the p-dopant comprises a quinone derivative, a metal oxide, a cyano group-containing compound, or any combination thereof.

* * * * *

专利名称(译)	杂环化合物和包括其的有机发光装置		
公开(公告)号	US20180019406A1	公开(公告)日	2018-01-18
申请号	US15/425351	申请日	2017-02-06
[标]申请(专利权)人(译)	三星显示有限公司		
申请(专利权)人(译)	三星DISPLAY CO. , LTD.		
当前申请(专利权)人(译)	三星DISPLAY CO. , LTD.		
[标]发明人	LEE HYOYOUNG KIM YOUNGKOOK PARK JUNHA SIM MUNKI JEONG EUNJAE HWANG SEOKHWAN		
发明人	LEE, HYOYOUNG KIM, YOUNGKOOK PARK, JUNHA SIM, MUNKI JEONG, EUNJAE HWANG, SEOKHWAN		
IPC分类号	H01L51/00 C07F9/6561 H01L51/50 C07D471/14 C07D487/04 C07D491/147		
CPC分类号	H01L51/0072 H01L51/5004 H01L51/0077 C07D487/04 H01L51/0067 H01L51/0073 H01L2251/552 C07F9/6561 H01L51/0071 C07D491/147 H01L51/0052 H01L51/5072 H01L51/506 C07D471/14		
优先权	1020160090775 2016-07-18 KR		
其他公开文献	US10069085		
外部链接	Espacenet USPTO		

摘要(译)

杂环化合物由式1表示： 其中，在式1中，R 1 ro R 4 ，R 11 ，环A 1 ，L 1 ，Ar 1 ，c11，a1和b1如说明书中所定义。

40

220
190
150
110
210