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

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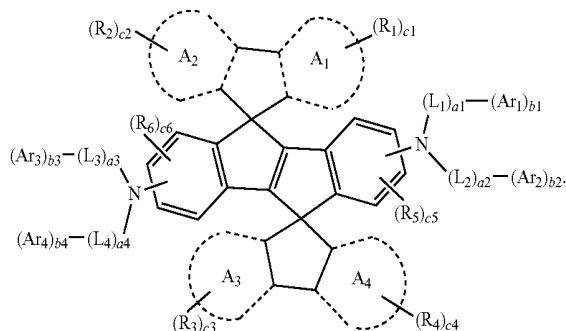
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(57) **ABSTRACT**  
A condensed-cyclic compound and an organic light-emitting device including the same, the compound being represented by Formula 1

Formula 1

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**40**

<b>220</b>
<b>190</b>
<b>150</b>
<b>110</b>
<b>210</b>

**FIG. 1**

**10**

<b>190</b>
<b>150</b>
<b>110</b>

# FIG. 2

20

<b>190</b>
<b>150</b>
<b>110</b>
<b>210</b>

**FIG. 3**

**30**

<b>220</b>
<b>190</b>
<b>150</b>
<b>110</b>

# FIG. 4

40

<b>220</b>
<b>190</b>
<b>150</b>
<b>110</b>
<b>210</b>

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

CROSS-REFERENCE TO RELATED  
APPLICATION

[0001] Korean Patent Application No. 10-2016-0104495, filed on Aug. 17, 2016, in the Korean Intellectual Property Office, and entitled: "Condensed-Cyclic Compound and Organic Light-Emitting Device Comprising the Same," is incorporated by reference herein in its entirety.

BACKGROUND

1. Field

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

2. Description of the Related Art

[0003] Organic light-emitting devices are self-emission devices; have wide viewing angles, high contrast ratios, short response times, and excellent luminance, driving voltage, and response speed characteristics; and produce full-color images.

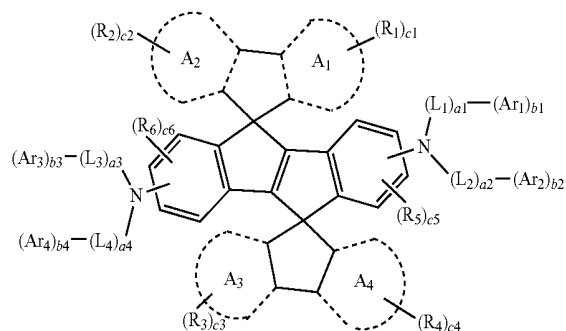
[0004] An example of such organic light-emitting devices may include a first electrode disposed on a substrate, and a hole transport region, an emission layer, an electron transport region, and a second electrode, which are sequentially disposed on the first electrode in this stated order. Holes provided 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, to thereby generate light.

SUMMARY

[0005] Embodiments are directed to a condensed-cyclic compound and an organic light-emitting device including the same.

[0006] The embodiments may be realized by providing a condensed-cyclic compound represented by Formula 1:

Formula 1



[0007] wherein, in Formula 1,  $A_1$  to  $A_4$  are each independently selected from a  $C_6-C_{60}$  carbocyclic group and a  $C_2-C_{60}$  heterocyclic group,  $L_1$  to  $L_4$  are each independently selected from a substituted or unsubstituted  $C_3-C_{10}$  cycloalkylene group, a substituted or unsubstituted  $C_1-C_{10}$  heterocycloalkylene group, a substituted or unsubstituted  $C_3-C_{10}$  cycloalkenylene group, a substituted or unsubstituted  $C_1-C_{10}$  heterocycloalkenylene group, a substituted or unsubstituted  $C_6-C_{60}$  arylene group, a substituted or unsubstituted  $C_1-C_{60}$  heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,  $a_1$  to  $a_4$  are each independently an integer of 0 to 3; when  $a_1$  is 2 or greater,  $L_1(s)$  are identical to or different from each other, when  $a_2$  is 2 or greater,  $L_2(s)$  are identical to or different from each other, when  $a_3$  is 2 or greater,  $L_3(s)$  are identical to or different from each other, when  $a_4$  is 2 or greater,  $L_4(s)$  are identical to or different from each other,  $Ar_1$  to  $Ar_4$  are each independently selected from a substituted or unsubstituted  $C_3-C_{10}$  cycloalkyl group, a substituted or unsubstituted  $C_1-C_{10}$  heterocycloalkyl group, a substituted or unsubstituted  $C_3-C_{10}$  cycloalkenyl group, a substituted or unsubstituted  $C_1-C_{10}$  heterocycloalkenyl group, a substituted or unsubstituted  $C_6-C_{60}$  aryl group, a substituted or unsubstituted  $C_6-C_{60}$  aryloxy group, a substituted or unsubstituted  $C_6-C_{60}$  arylthio group, a substituted or unsubstituted  $C_1-C_{60}$  heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group,  $b_1$  to  $b_4$  are each independently an integer of 1 to 5; when  $b_1$  is 2 or greater,  $Ar_1(s)$  are identical to or different from each other, when  $b_2$  is 2 or greater,  $Ar_2(s)$  are identical to or different from each other, when  $b_3$  is 2 or greater,  $Ar_3(s)$  are identical to or different from each other, when  $b_4$  is 2 or greater,  $Ar_4(s)$  are identical to or different from each other,  $R_1$  to  $R_6$  are each independently selected from hydrogen, deuterium,  $-F$ ,  $-Cl$ ,  $-Br$ ,  $-I$ , a hydroxy 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, and  $-Si(Q_1)(Q_2)(Q_3)$ ,  $c_1$  and  $c_4$  are each independently an integer of 0 to 6; when  $c_1$  is 2 or greater,  $R_1(s)$  are identical to or different from each other, when  $c_2$  is 2 or greater,  $R_2(s)$  are identical to or different

from each other, when c3 is 2 or greater, R<sub>3</sub>(s) are identical to or different from each other, when c4 is 2 or greater, R<sub>4</sub>(s) are identical to or different from each other, c5 and c6 are each independently an integer of 0 to 3; when c5 is 2 or greater, R<sub>5</sub>(s) are identical to or different from each other, when c6 is 2 or greater, R<sub>6</sub>(s) are identical to or different from each other, and at least one substituent of the substituted C<sub>3</sub>-C<sub>10</sub> cycloalkylene group, substituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkylene group, substituted C<sub>3</sub>-C<sub>10</sub> cycloalkenylene group, substituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkenylene group, substituted C<sub>6</sub>-C<sub>60</sub> arylene group, substituted C<sub>1</sub>-C<sub>60</sub> heteroarylene group, substituted divalent non-aromatic condensed polycyclic group, substituted divalent non-aromatic condensed heteropolycyclic group, substituted C<sub>1</sub>-C<sub>60</sub> alkyl group, substituted C<sub>2</sub>-C<sub>60</sub> alkenyl group, substituted C<sub>2</sub>-C<sub>60</sub> alkynyl group, substituted C<sub>1</sub>-C<sub>60</sub> alkoxy group, substituted C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, substituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, substituted C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, substituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, substituted C<sub>6</sub>-C<sub>60</sub> aryl group, substituted C<sub>6</sub>-C<sub>60</sub> aryloxy group, substituted C<sub>6</sub>-C<sub>60</sub> arylthio group, substituted C<sub>1</sub>-C<sub>60</sub> heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic condensed heteropolycyclic group is selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C<sub>1</sub>-C<sub>60</sub> alkyl group, a C<sub>2</sub>-C<sub>60</sub> alkenyl group, a C<sub>2</sub>-C<sub>60</sub> alkynyl group, and a C<sub>1</sub>-C<sub>60</sub> alkoxy group; a C<sub>1</sub>-C<sub>60</sub> alkyl group, a C<sub>2</sub>-C<sub>60</sub> alkenyl group, a C<sub>2</sub>-C<sub>60</sub> alkynyl group, and a C<sub>1</sub>-C<sub>60</sub> alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C<sub>1</sub>-C<sub>60</sub> alkyl group, a C<sub>2</sub>-C<sub>60</sub> alkenyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>6</sub>-C<sub>60</sub> aryloxy group, a C<sub>6</sub>-C<sub>60</sub> arylthio group, a C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —Si(Q<sub>11</sub>)(Q<sub>12</sub>)(Q<sub>13</sub>), —N(Q<sub>11</sub>)(Q<sub>12</sub>), —B(Q<sub>11</sub>)(Q<sub>12</sub>), —C(=O)(Q<sub>11</sub>), —S(=O)<sub>2</sub>(Q<sub>11</sub>), and —P(=O)(Q<sub>11</sub>)(Q<sub>12</sub>); a C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>6</sub>-C<sub>60</sub> aryloxy group, a C<sub>6</sub>-C<sub>60</sub> arylthio group, a C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group; a C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>6</sub>-C<sub>60</sub> aryloxy group, a C<sub>6</sub>-C<sub>60</sub> arylthio group, a C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C<sub>1</sub>-C<sub>60</sub> alkyl group, a C<sub>2</sub>-C<sub>60</sub> alkenyl group, a C<sub>2</sub>-C<sub>60</sub> alkynyl group, a C<sub>1</sub>-C<sub>60</sub> alkoxy group,

C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>6</sub>-C<sub>60</sub> aryloxy group, a C<sub>6</sub>-C<sub>60</sub> arylthio group, a C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —Si(Q<sub>21</sub>)(Q<sub>22</sub>)(Q<sub>23</sub>), —N(Q<sub>21</sub>)(Q<sub>22</sub>), —B(Q<sub>21</sub>)(Q<sub>22</sub>), —C(=O)(Q<sub>21</sub>), —S(=O)<sub>2</sub>(Q<sub>21</sub>), and —P(=O)(Q<sub>21</sub>)(Q<sub>22</sub>); and —Si(Q<sub>31</sub>)(Q<sub>32</sub>)(Q<sub>33</sub>), —N(Q<sub>31</sub>)(Q<sub>32</sub>), —B(Q<sub>31</sub>)(Q<sub>32</sub>), —C(=O)(Q<sub>31</sub>), —S(=O)<sub>2</sub>(Q<sub>31</sub>), and —P(=O)(Q<sub>31</sub>)(Q<sub>32</sub>), wherein Q<sub>1</sub> to Q<sub>3</sub>, Q<sub>11</sub> to Q<sub>13</sub>, Q<sub>21</sub> to Q<sub>23</sub>, and Q<sub>31</sub> to Q<sub>33</sub> 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<sub>1</sub>-C<sub>60</sub> alkyl group, a C<sub>2</sub>-C<sub>60</sub> alkenyl group, a C<sub>2</sub>-C<sub>60</sub> alkynyl group, a C<sub>1</sub>-C<sub>60</sub> alkoxy group, a C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

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

#### BRIEF DESCRIPTION OF THE DRAWINGS

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

**[0010]** FIGS. 1 to 4 illustrate each a schematic view of an organic light-emitting device according to an embodiment.

#### DETAILED DESCRIPTION

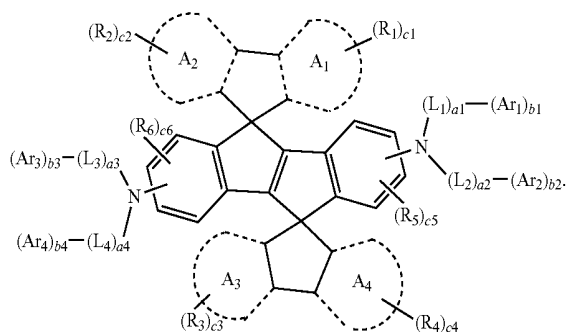
**[0011]** In the drawing figures, the dimensions of layers and regions may be exaggerated for clarity of illustration. It will also be understood that when a layer or element is referred to as being “on” another layer or element, it can be directly on the other layer or substrate, or intervening layers 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.

**[0012]** Reference will now be made in detail to embodiments, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout. In this regard, the present embodiments may have different forms and should not be construed as being limited to the descriptions set forth herein. Accordingly, the embodiments are merely described below, by referring to the figures, to explain aspects of the present description. As used herein, the terms “or” and “and/or” include any and all combinations of one or more of the associated listed items. Expressions such as “at least one of” when preceding a list of elements, modify the entire list of

elements and do not modify the individual elements of the list.

[0013] A condensed-cyclic compound according to an embodiment may be represented by Formula 1.

Formula 1



[0014] In Formula 1, descriptions of  $A_1$  to  $A_4$ ,  $L_1$  to  $L_4$ ,  $a_1$  to  $a_4$ ,  $Ar_1$  to  $Ar_4$ ,  $b_1$  to  $b_4$ ,  $R_1$  to  $R_6$ , and  $c_1$  to  $c_4$  may each independently be the same as descriptions thereof provided herein.

[0015]  $A_1$  to  $A_4$  in Formula 1 may each independently be, e.g., a  $C_6$ - $C_{60}$  carbocyclic group or a  $C_2$ - $C_{60}$  heterocyclic group.

[0016] In an implementation,  $A_1$  to  $A_4$  may each independently be selected from, e.g.,

[0017] a benzene group, a naphthalene group, and an anthracene group; and

[0018] a pyridine group, a pyridazine group, a pyrimidine group, a pyrazine group, a triazine group, a quinoline group, an isoquinoline group, a phthalazine group, naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a benzothiophene group, a benzofuran group, a dibenzothiophene group, and a dibenzofuran group.

[0019] In an implementation,  $A_1$  to  $A_4$  may each independently be selected from, e.g., a benzene group, a naphthalene group, a pyridine group, a quinoline group, an isoquinoline group, a dibenzothiophene group, and a dibenzofuran group.

[0020] In an implementation,  $A_1$  to  $A_4$  may each be identical to or different from each other.

[0021] In an implementation,  $A_1$  and  $A_3$  may be identical to each other, and  $A_2$  and  $A_4$  may be identical to each other. In an implementation,  $A_1$  and  $A_2$  may be identical to each other, and  $A_3$  and  $A_4$  may be identical to each other. In an implementation,  $A_1$  and  $A_4$  may be identical to each other, and  $A_2$  and  $A_3$  may be identical to each other. In an implementation,  $A_1$  to  $A_4$  may all be identical to one another. In an implementation,  $A_1$  to  $A_4$  may all be different from one another.

[0022] In an implementation,  $A_1$  and  $A_3$  may each independently be selected from, e.g., a benzene group, a naphthalene group, a pyridine group, a quinoline group, an isoquinoline group, a dibenzothiophene group, and a dibenzofuran group.

[0023] In an implementation,  $A_2$  and  $A_4$  may both be a benzene group.

[0024] In an implementation,  $L_1$  to  $L_4$  in Formula 1 may each independently be selected from or include, e.g., a substituted or unsubstituted  $C_3$ - $C_6$  cycloalkylene group, a substituted or unsubstituted  $C_1$ - $C_{10}$  heterocycloalkylene group, a substituted or unsubstituted  $C_3$ - $C_{10}$  cycloalk-

ylene group, a substituted or unsubstituted  $C_1$ - $C_{10}$  heterocycloalkylene 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.

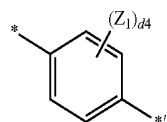
[0025] In an implementation,  $L_1$  to  $L_4$  in Formula 1 may each independently be selected from, e.g.,

[0026] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylylene group, a hexacenylylene group, a pentacenylylene group, a thiophenylylene group, a furanylylene group, a carbazolylylene group, an indolylylene group, an isoindolylylene group, a benzofuranylylene group, a benzothiophenylylene group, a dibenzofuranylylene group, a dibenzothiophenylylene group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, a pyridinylylene group, an imidazolylylene group, a pyrazolylylene group, a thiazolylylene group, an isothiazolylylene group, an oxazolylylene group, an isoxazolylylene group, a thiadiazolylylene group, an oxadiazolylylene group, a pyrazinylylene group, a pyrimidinylylene group, a pyridazinylylene group, a triazininylylene group, a quinolininylylene group, an isoquinolininylylene group, a benzoquinolininylylene group, a phthalazininylylene group, a naphthyridinylylene group, a quinoxalinylylene group, a quinazolinylylene group, a cinnolininylylene group, a phenanthridinylylene group, an acridinylylene group, a phenanthrolinylylene group, a phenazininylylene group, a benzimidazolylylene group, an isobenzothiazolylylene group, a benzoxazolylylene group, an isobenzoxazolylylene group, a triazolylylene group, a tetrazolylylene group, an imidazopyridinylylene group, an imidazopyrimidinylylene group, and an azacarbazolylylene group; and

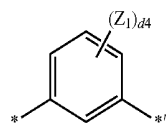
[0027] a phenylene group, a naphthylene group, a fluorenylylene group, a spiro-bifluorenylylene group, a benzofluorenylylene group, a dibenzofluorenylylene group, a phenanthrenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylylene group, a hexacenylylene group, a pentacenylylene group, a thiophenylylene group, a furanylylene group, a carbazolylylene group, an indolylylene group, an isoindolylylene group, a benzofuranylylene group, a benzothiophenylylene group, a dibenzofuranylylene group, a dibenzothiophenylylene group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, a pyridinylylene group, an imidazolylylene group, a pyrazolylylene group, a thiazolylylene group, an isothiazolylylene group, an oxazolylylene group, an isoxazolylylene group, a thiadiazolylylene group, an oxadiazolylylene group, a pyrazinylylene group, a pyrimidinylylene group, a pyridazinylylene group, a triazininylylene group, a quinolininylylene group, an isoquinolininylylene group, a benzoquinolininylylene group, a phthalazininylylene group, a naphthyridinylylene group, a quinoxalinylylene group, a quinazolinylylene group, a cinnolininylylene group, a phenanthridinylylene group, an acridinylylene group, a phenanthrolinylylene group, a phenazininylylene group, a benzimidazolylylene group, an isobenzothiazolylylene group, a benzoxazolylylene group, an isobenzoxazolylylene group, a triazolylylene group, a tetrazolylylene group, an imidazopyridinylylene group, an imidazopyrimidinylylene group, and an

azacarbazolylylene 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<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>1</sub>-C<sub>20</sub> 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 penta-phenyl group, a hexacenylyl group, a pentacenylyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group.

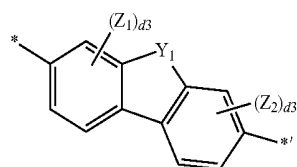
[0028] In an implementation, L<sub>1</sub> to L<sub>4</sub> in Formula 1 may each independently be selected from, e.g., groups represented by Formulae 3-1 to 3-46:



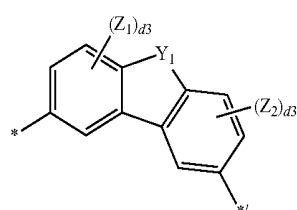
Formula 3-1



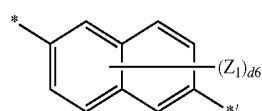
Formula 3-2



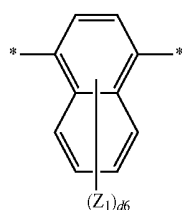
Formula 3-3



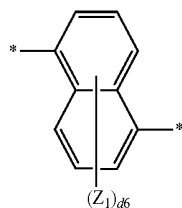
Formula 3-4



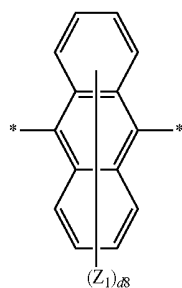
Formula 3-5



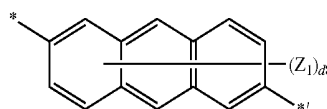
Formula 3-6



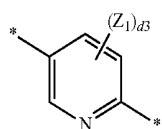
Formula 3-7



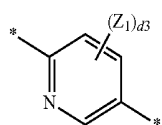
Formula 3-8



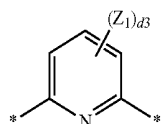
Formula 3-9



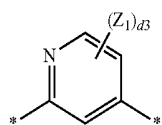
Formula 3-10



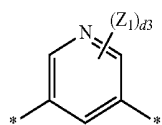
Formula 3-11



Formula 3-12



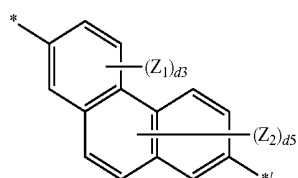
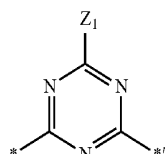
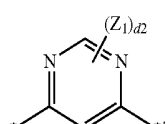
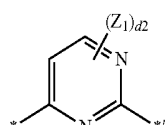
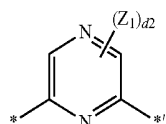
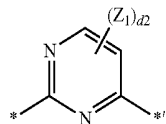
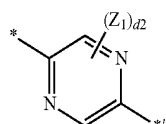
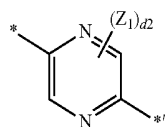
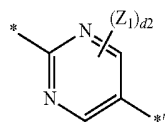
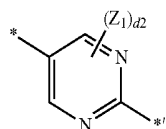
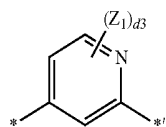
Formula 3-13



Formula 3-14

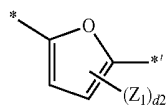
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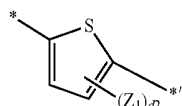


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Formula 3-15

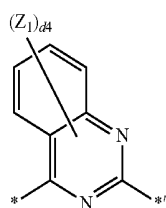


Formula 3-16



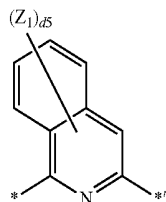
Formula 3-17

Formula 3-18



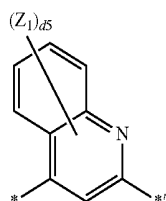
Formula 3-19

Formula 3-20

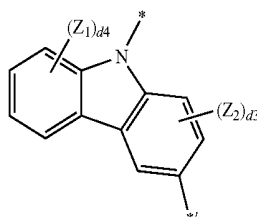


Formula 3-21

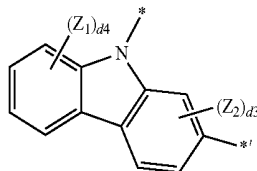
Formula 3-22



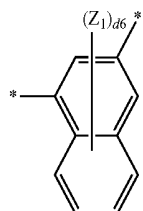
Formula 3-23



Formula 3-24



Formula 3-25



Formula 3-26

Formula 3-27

Formula 3-28

Formula 3-29

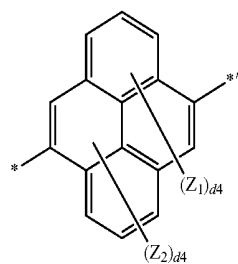
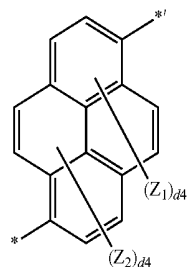
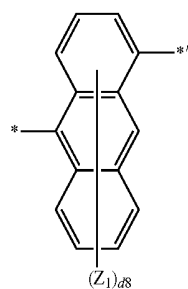
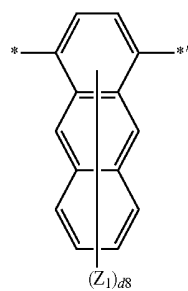
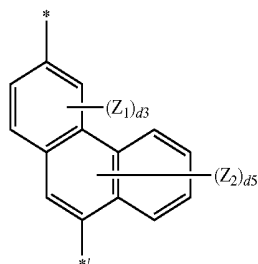
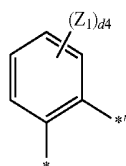
Formula 3-30

Formula 3-31

Formula 3-32

Formula 3-33

-continued



Formula 3-34

Formula 3-35

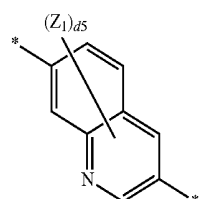
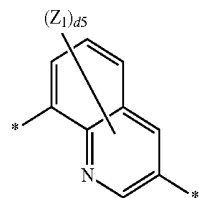
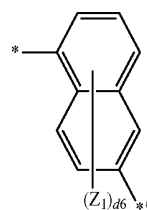
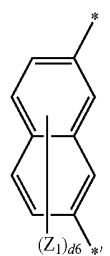
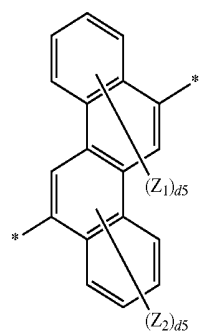
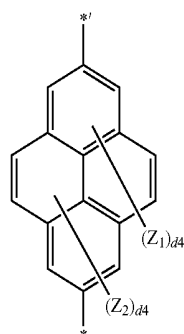
Formula 3-36

Formula 3-37

Formula 3-38

Formula 3-39

-continued



Formula 3-40

Formula 3-41

Formula 3-42

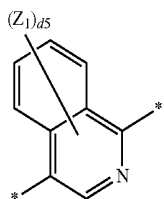
Formula 3-43

Formula 3-44

Formula 3-45

-continued

Formula 3-46



[0029] In Formulae 3-1 to 3-46,

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

[0031]  $Z_1$  to  $Z_7$  may each independently be selected from, e.g., hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a  $C_1$ - $C_{20}$  alkyl group, a  $C_1$ - $C_{20}$  alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-benzofluorene-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an indolyl group, an isoindolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, an isoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, a benzosilolyl group, a benzothiazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphthosilolyl group, a thiadiazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafuorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indenocarbazolyl group, and an indolocarbazolyl group,

[0032]  $d_2$  may be, e.g., an integer of 0 to 2,

[0033]  $d_3$  may be, e.g., an integer of 0 to 3,

[0034]  $d_4$  may be, e.g., an integer of 1 to 4,

[0035]  $d_5$  may be, e.g., an integer of 1 to 5,

[0036]  $d_6$  may be, e.g., an integer of 1 to 6, and

[0037]  $d_8$  may be, e.g., an integer of 1 to 8.

[0038] In an implementation,  $L_1$  to  $L_4$  may each independently be selected from, e.g., groups represented by Formulae 3-1, 3-2, and 3-34.

[0039] In an implementation,  $a_1$  to  $a_4$  in Formula 1 may each independently be, e.g., an integer of 0 to 3.

[0040] In an implementation,  $a_1$  to  $a_3$  in Formula 1 may each independently be 0, 1, or 2. In an implementation,  $a_1$  to  $a_3$  in Formula 1 may each independently be 0 or 1.

[0041] When  $a_1$  is 2 or greater,  $L_1(s)$  may be identical to or different from each other, when  $a_2$  is 2 or greater,  $L_2(s)$  may be identical to or different from each other, when  $a_3$  is 2 or greater,  $L_3(s)$  may be identical to or different from each other, and when  $a_4$  is 2 or greater,  $L_4(s)$  may be identical to or different from each other.

[0042] In an implementation,  $Ar_1$  to  $Ar_4$  in Formula 1 may each independently be selected from or include, e.g., a substituted or unsubstituted  $C_3$ - $C_{10}$  cycloalkyl group, a substituted or unsubstituted  $C_1$ - $C_{10}$  heterocycloalkyl group, a substituted or unsubstituted  $C_3$ - $C_{10}$  cycloalkenyl group, a substituted or unsubstituted  $C_1$ - $C_{10}$  heterocycloalkenyl group, a substituted or unsubstituted  $C_6$ - $C_{60}$  aryl group, a substituted or unsubstituted  $C_6$ - $C_{60}$  aryloxy group, a substituted or unsubstituted  $C_6$ - $C_{60}$  arylthio group, a substituted or unsubstituted  $C_1$ - $C_{60}$  heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group.

[0043] In an implementation,  $Ar_1$  to  $Ar_4$  in Formula 1 may each independently be selected from, e.g.,

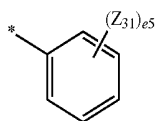
[0044] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group; and

[0045] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group,

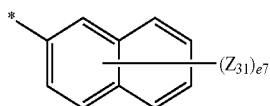
a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>1</sub>-C<sub>20</sub> 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 benzofuran group, a benzothiophenyl group, a dibenzofuran group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an azacarbazolyl group, and —Si(Q<sub>11</sub>)(Q<sub>12</sub>)(Q<sub>13</sub>),

**[0046]** wherein Q<sub>11</sub> to Q<sub>13</sub> may each independently be selected from, e.g., a C<sub>1</sub>-C<sub>10</sub> alkyl group, a C<sub>1</sub>-C<sub>10</sub> alkoxy group, a phenyl group, a biphenyl group, and a terphenyl group.

**[0047]** In an implementation, Ar<sub>1</sub> to Ar<sub>4</sub> in Formula 1 may each independently be selected from, e.g., groups represented by Formulae 5-1 to 5-79.

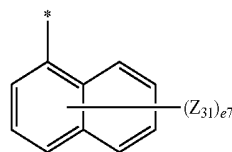


Formula 5-1

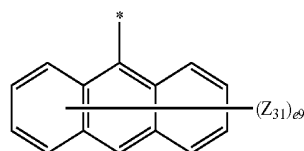


Formula 5-2

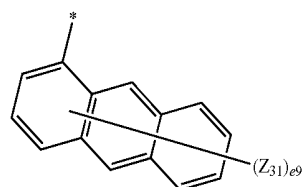
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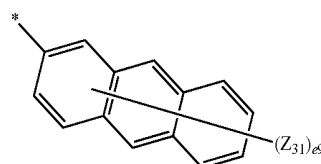
Formula 5-3



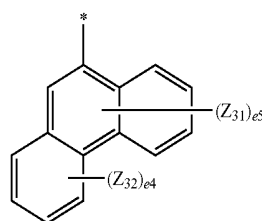
Formula 5-4



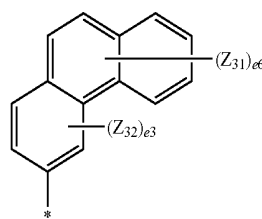
Formula 5-5



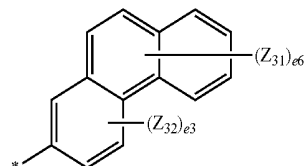
Formula 5-6



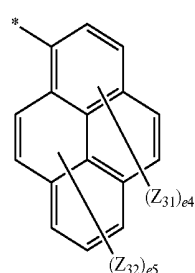
Formula 5-7



Formula 5-8



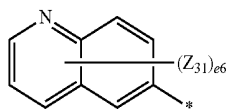
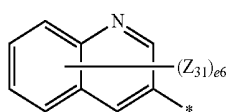
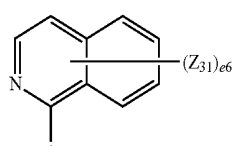
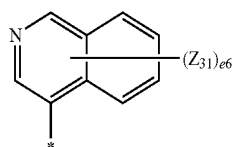
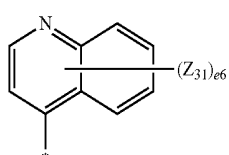
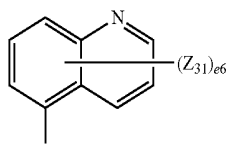
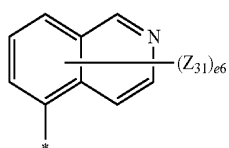
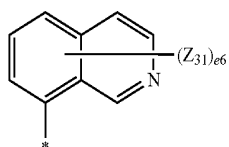
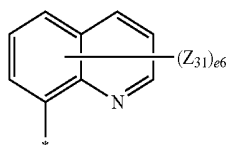
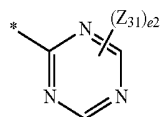
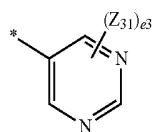
Formula 5-9



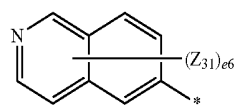
Formula 5-10



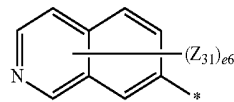
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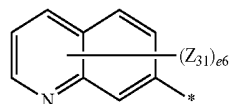
Formula 5-27



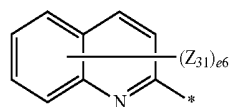
Formula 5-28



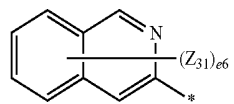
Formula 5-29



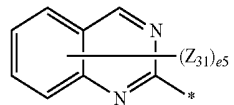
Formula 5-30



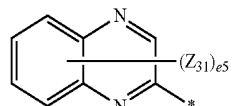
Formula 5-31



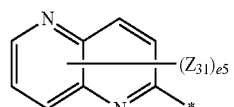
Formula 5-32



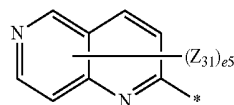
Formula 5-33



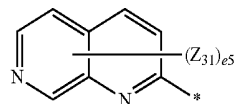
Formula 5-34



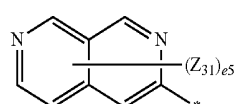
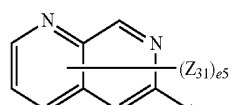
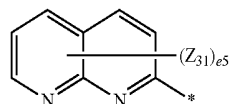
Formula 5-35



Formula 5-36



Formula 5-37



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Formula 5-38

Formula 5-39

Formula 5-40

Formula 5-41

Formula 5-42

Formula 5-43

Formula 5-44

Formula 5-45

Formula 5-46

Formula 5-47

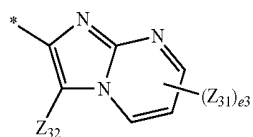
Formula 5-48

Formula 5-49

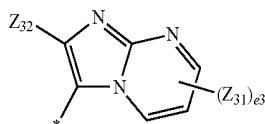
Formula 5-50



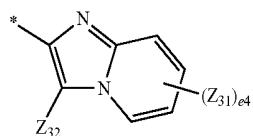
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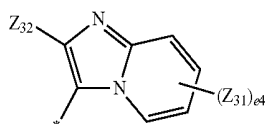
Formula 5-72



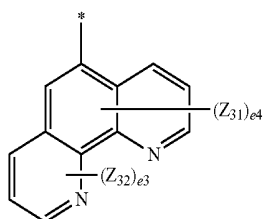
Formula 5-73



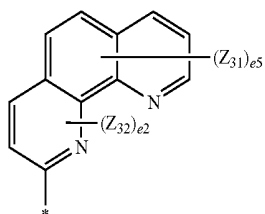
Formula 5-74



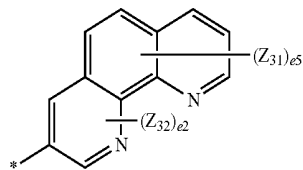
Formula 5-75



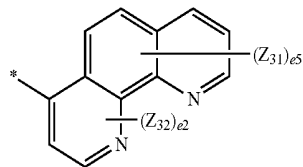
Formula 5-76



Formula 5-77



Formula 5-78



Formula 5-79

[0048] In Formulae 5-1 to 5-79,

[0049]  $Y_{31}$  may be selected from, e.g., O, S,  $C(Z_{35})(Z_{36})$ ,  $N(Z_{37})$ , and  $Si(Z_{38})(Z_{39})$ ,[0050]  $Z_{31}$  to  $Z_{39}$  may each independently be selected from, e.g., hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a  $C_1$ - $C_{20}$  alkyl group, a  $C_1$ - $C_{20}$  alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a

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

—Si( $Q_{11}$ )( $Q_{12}$ )( $Q_{13}$ ),[0051] wherein  $Q_{11}$  to  $Q_{13}$  may each independently be selected from, e.g., a  $C_1$ - $C_{10}$  alkyl group, a  $C_1$ - $C_{10}$  alkoxy group, a phenyl group, a biphenyl group, and a terphenyl group,

[0052] e2 may be, e.g., an integer of 0 and 2,

[0053] e3 may be, e.g., an integer of 0 to 3,

[0054] e4 may be, e.g., an integer of 0 to 4,

[0055] e5 may be, e.g., an integer of 0 to 5,

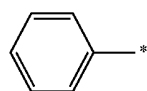
[0056] e6 may be, e.g., an integer of 0 to 6,

[0057] e7 may be, e.g., an integer of 0 to 7, and

[0058] e9 may be, e.g., an integer of 0 to 9.

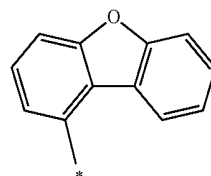
[0059] In an implementation,  $Ar_1$  to  $Ar_4$  may each independently be selected from, e.g., groups represented by Formulae 5-1 to 5-3, 5-13 to 5-19, and 5-21 to 5-28. In an implementation,  $Ar_1$  to  $Ar_4$  may each independently be selected from, e.g., groups represented by Formulae 5-1, 5-2, 5-15, 5-16, and 5-22.[0060] In an implementation,  $Ar_1$  to  $Ar_4$  in Formula 1 may each independently be selected from, e.g., groups represented by Formulae 6-1 to 6-14.

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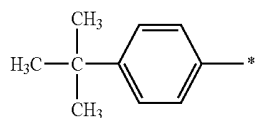
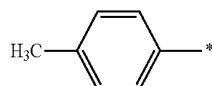
Formula 6-1

Formula 6-12

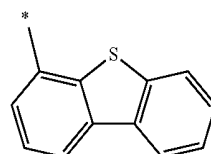


Formula 6-2

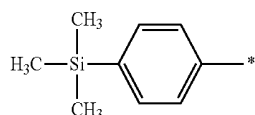
Formula 6-13



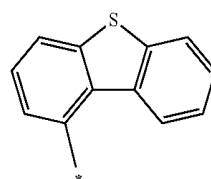
Formula 6-3



Formula 6-14

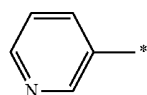


Formula 6-4



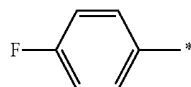
Formula 6-5

**[0061]** In an implementation, b1 to b4 in Formula 1 may each independently be, e.g., an integer from 1 to 5.



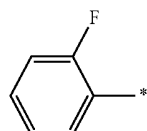
Formula 6-6

**[0062]** In an implementation, b1 to b4 in Formula 1 may each independently be, e.g., an integer of 1 to 4. In an implementation, b1 to b4 in Formula 1 may each independently be, e.g., an integer of 1 to 3. In an implementation, b1 to b4 in Formula 1 may each independently be, e.g., 1 or 2.



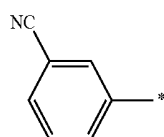
Formula 6-7

**[0063]** When b1 is 2 or greater, Ar<sub>1</sub>(s) may be identical to or different from each other, when b2 is 2 or greater, Ar<sub>2</sub>(s) may be identical to or different from each other, when b3 is 2 or greater, Ar<sub>3</sub>(s) may be identical to or different from each other, and when b4 is 2 or greater, Ar<sub>4</sub>(s) may be identical to or different from each other.

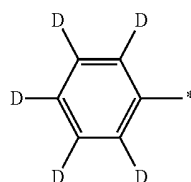


Formula 6-8

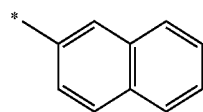
**[0064]** In an implementation, R<sub>1</sub> to R<sub>6</sub> in Formula 1 may each independently be selected from, e.g., hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C<sub>1</sub>-C<sub>60</sub> alkyl group, a substituted or unsubstituted C<sub>2</sub>-C<sub>60</sub> alkenyl group, a substituted or unsubstituted C<sub>2</sub>-C<sub>60</sub> alkynyl group, a substituted or unsubstituted C<sub>1</sub>-C<sub>60</sub> alkoxy group, a substituted or unsubstituted C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a substituted or unsubstituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a substituted or unsubstituted C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a substituted or unsubstituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a substituted or unsubstituted C<sub>6</sub>-C<sub>60</sub> aryl group, a substituted or unsubstituted C<sub>6</sub>-C<sub>60</sub> aryloxy group, a substituted or unsubstituted C<sub>6</sub>-C<sub>60</sub> arylthio group, a substituted or unsubstituted C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, and —Si(Q<sub>1</sub>)(Q<sub>2</sub>)(Q<sub>3</sub>) (in which Q<sub>1</sub> to Q<sub>3</sub> are the same as described above).



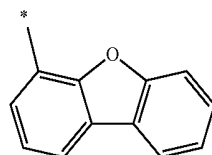
Formula 6-9



Formula 6-10



Formula 6-11



**[0065]** In an implementation, R<sub>1</sub> to R<sub>6</sub> in Formula 1 may each independently be selected from, e.g.,

**[0066]** —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C<sub>1</sub>-C<sub>20</sub> alkyl group, and a C<sub>1</sub>-C<sub>20</sub> alkoxy group;

**[0067]** a C<sub>1</sub>-C<sub>20</sub> alkyl group and a C<sub>1</sub>-C<sub>20</sub> 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, and a hydrazono group;

**[0068]** a cyclopentyl group, a cyclohexyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, and a terphenyl group;

**[0069]** a cyclopentyl group, a cyclohexyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>1</sub>-C<sub>20</sub> alkoxy group, a cyclopentyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, and a terphenyl group; and

**[0070]** —Si(Q<sub>1</sub>)(Q<sub>2</sub>)(Q<sub>3</sub>). Q<sub>1</sub> to Q<sub>3</sub> may each independently be selected from, e.g., a C<sub>1</sub>-C<sub>10</sub> alkyl group, a C<sub>1</sub>-C<sub>10</sub> alkoxy group, a phenyl group, a biphenyl group, and a terphenyl group.

**[0071]** In an implementation, R<sub>1</sub> to R<sub>6</sub> in Formula 1 may each independently be selected from, e.g.,

**[0072]** —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, and a C<sub>1</sub>-C<sub>20</sub> alkyl group;

**[0073]** a C<sub>1</sub>-C<sub>20</sub> alkyl 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, and a hydrazono group;

**[0074]** a phenyl group, a biphenyl group, and a terphenyl group;

**[0075]** a phenyl group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C<sub>1</sub>-C<sub>20</sub> alkyl group, a phenyl group, a biphenyl group, and a terphenyl group; and

**[0076]** —Si(Q<sub>1</sub>)(Q<sub>2</sub>)(Q<sub>3</sub>), wherein Q<sub>1</sub> to Q<sub>3</sub> may each be a C<sub>1</sub>-C<sub>10</sub> alkyl group.

**[0077]** In an implementation, c<sub>1</sub> and c<sub>4</sub> in Formula 1 may each independently be, e.g., an integer from 0 to 6.

**[0078]** In an implementation, c<sub>1</sub> and c<sub>4</sub> in Formula 1 may each independently be, e.g., an integer of 0 to 5. In an implementation, c and c<sub>4</sub> in Formula 1 may each independently be, e.g., an integer of 0 to 4. In an implementation, c<sub>1</sub> and c<sub>4</sub> in Formula 1 may each independently be, e.g., an integer of 0 to 3. In an implementation, c<sub>1</sub> and c<sub>4</sub> in Formula 1 may each independently be, e.g., an integer of 0 to 2.

**[0079]** When c<sub>1</sub> is 2 or greater, R<sub>1</sub>(s) may be identical to or different from each other, when c<sub>2</sub> is 2 or greater, R<sub>2</sub>(s) may be identical to or different from each other, when c<sub>3</sub> is 2 or greater, R<sub>3</sub>(s) may be identical to or different from each other, and when c<sub>4</sub> is 2 or greater, R<sub>4</sub>(s) may be identical to or different from each other.

**[0080]** In an implementation, c<sub>5</sub> and c<sub>6</sub> in Formula 1 may each independently be, e.g., an integer of 0 to 3.

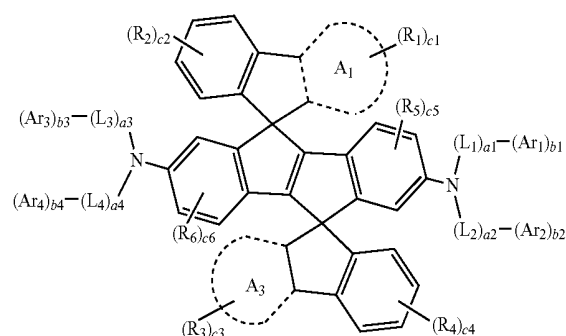
**[0081]** In an implementation, c<sub>5</sub> and c<sub>6</sub> in Formula 1 may each independently be, e.g., an integer of 0 to 2. In an implementation, c<sub>5</sub> and c<sub>6</sub> in Formula 1 may each independently be, e.g., an integer of 0 or 1.

**[0082]** When c<sub>5</sub> is 2 or greater, R<sub>5</sub>(s) may be identical to or different from each other, and when c<sub>6</sub> is 2 or greater, R<sub>6</sub>(s) may be identical to or different from each other.

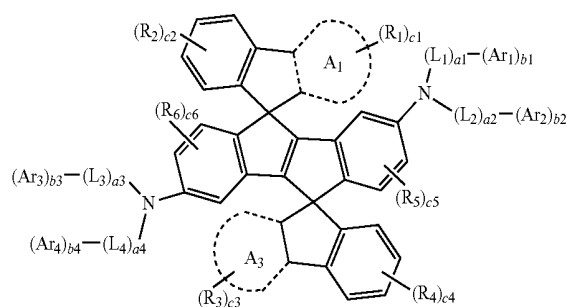
**[0083]** In an implementation, c<sub>1</sub> to c<sub>6</sub> in Formula 1 may each independently be, e.g., an integer of 0, 1, or 2.

**[0084]** In an implementation, the condensed-cyclic compound may be represented by one of Formulae 1-1 and 1-2.

Formula 1-1



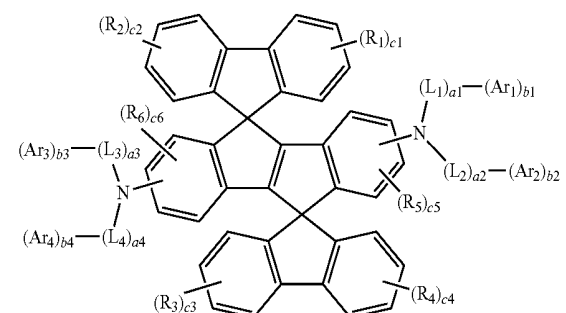
Formula 1-2



**[0085]** In Formulae 1-1 and 1-2, A<sub>1</sub>, A<sub>3</sub>, L<sub>1</sub> to L<sub>4</sub>, a<sub>1</sub> to a<sub>4</sub>, Ar<sub>1</sub> to Ar<sub>4</sub>, b<sub>1</sub> to b<sub>4</sub>, R<sub>1</sub> to R<sub>6</sub>, and c<sub>1</sub> to c<sub>6</sub> are the same as may be the same as those described herein.

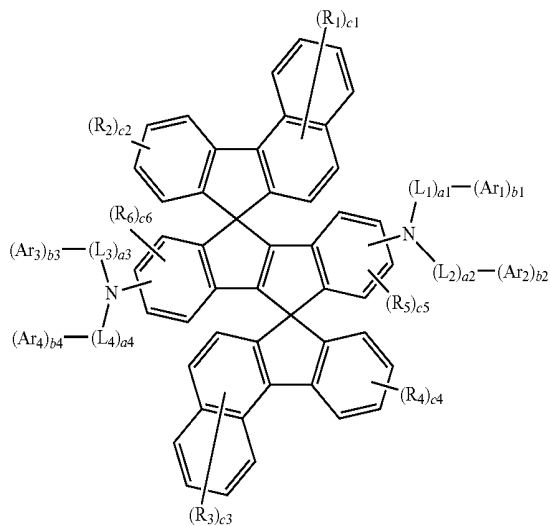
**[0086]** In an implementation, the condensed-cyclic compound may be represented by one of the following Formulae 1(1) to 1(26).

Formula 1(1)

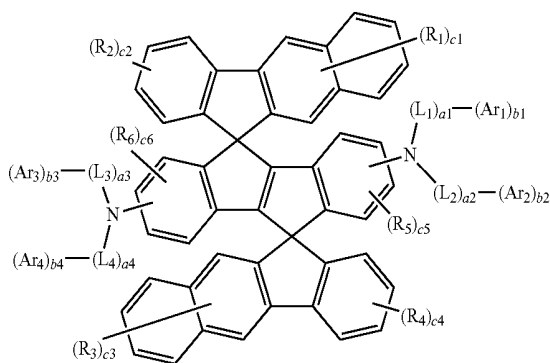


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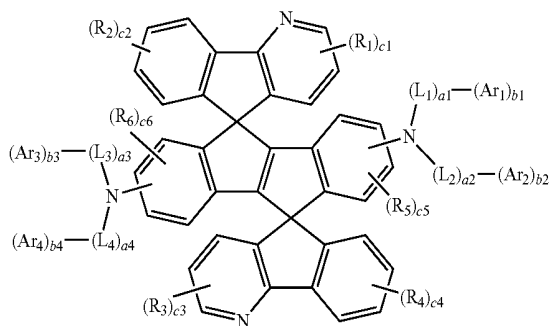
Formula 1(2)



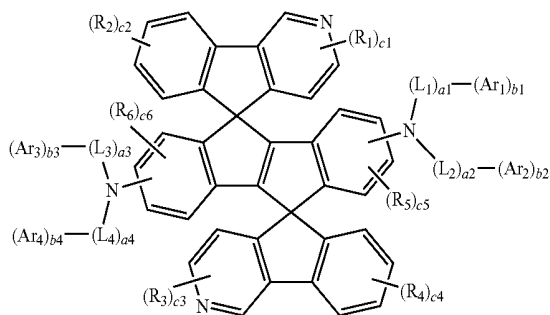
Formula 1(3)



Formula 1(4)

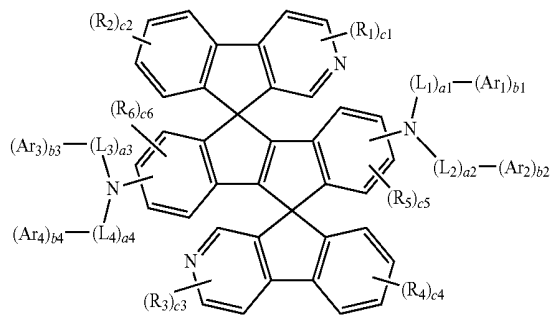


Formula 1(5)

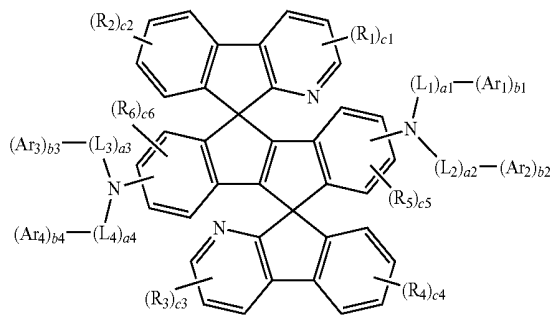


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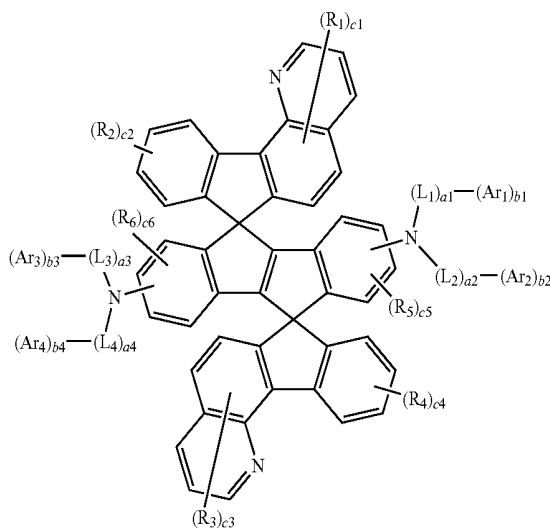
Formula 1(6)



Formula 1(7)

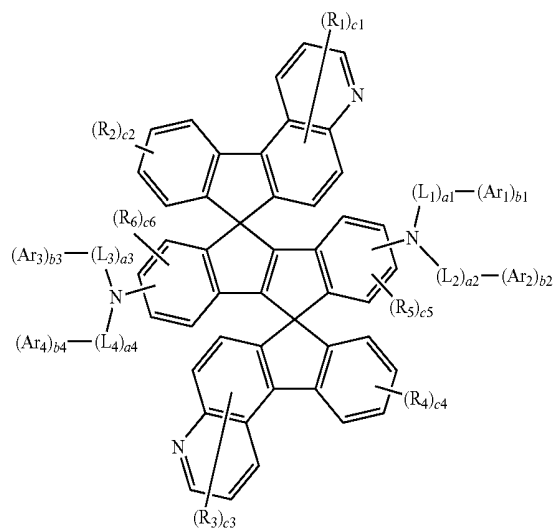


Formula 1(8)

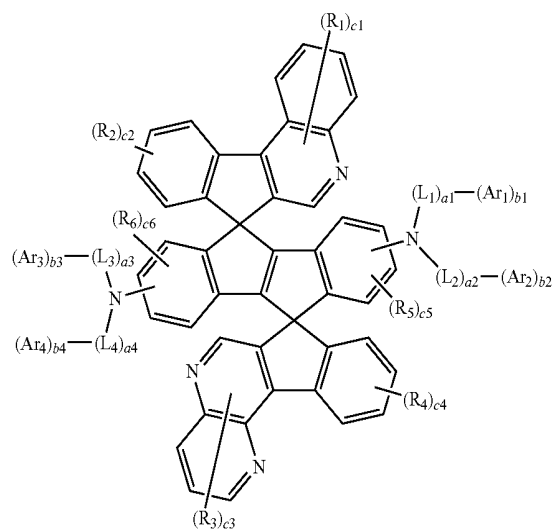


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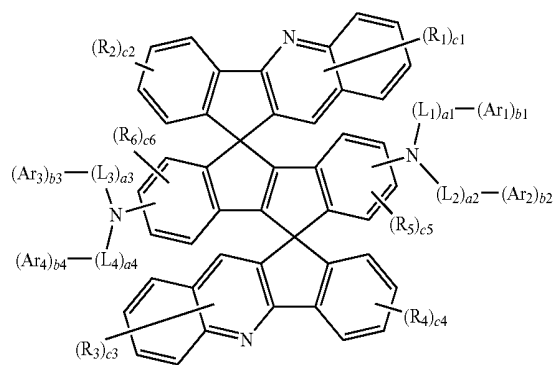
Formula 1(9)



Formula 1(10)

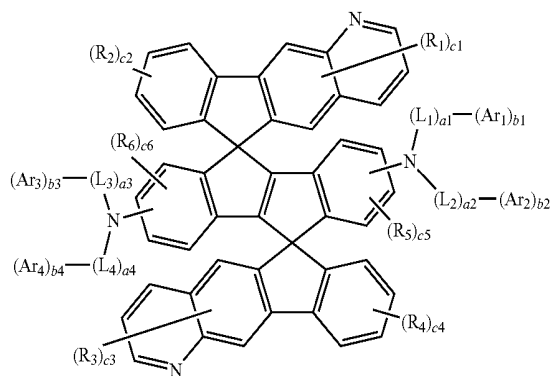


Formula 1(11)

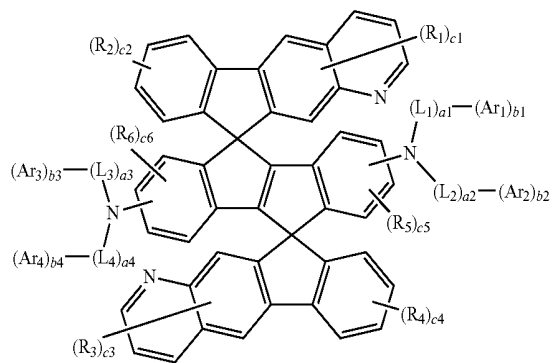


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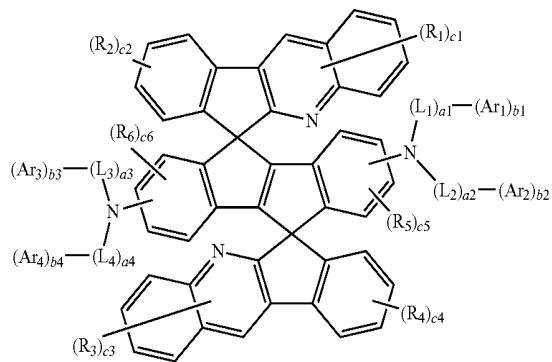
Formula 1(12)



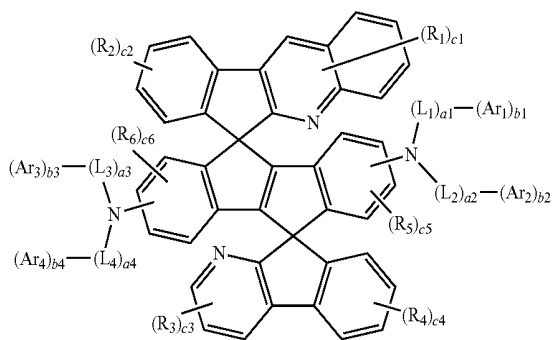
Formula 1(13)



Formula 1(14)



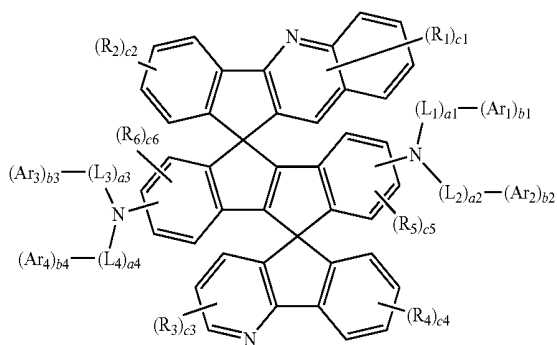
Formula 1(15)



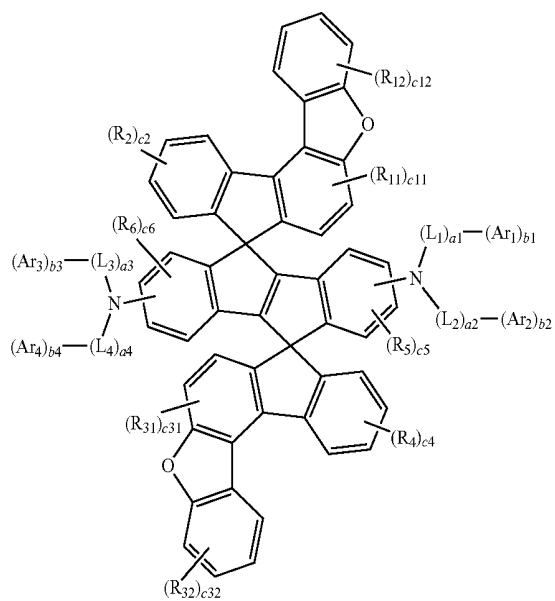
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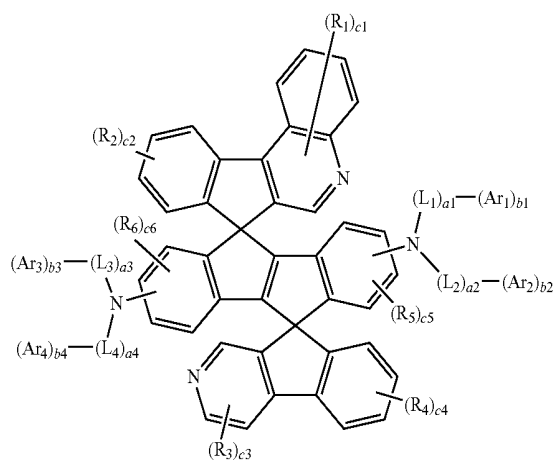
Formula 1(16)



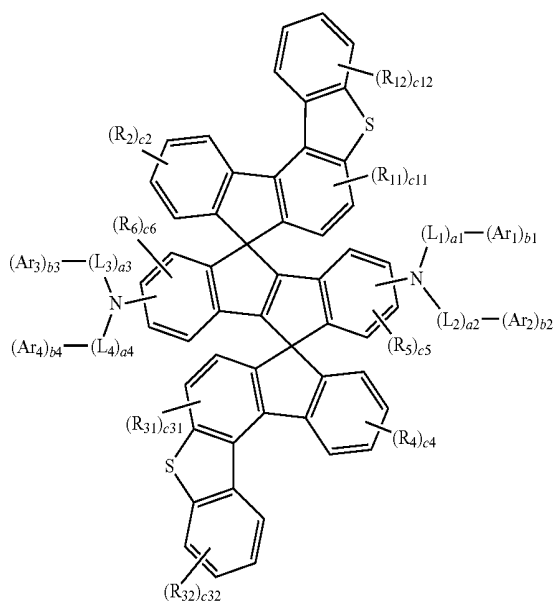
Formula 1(19)



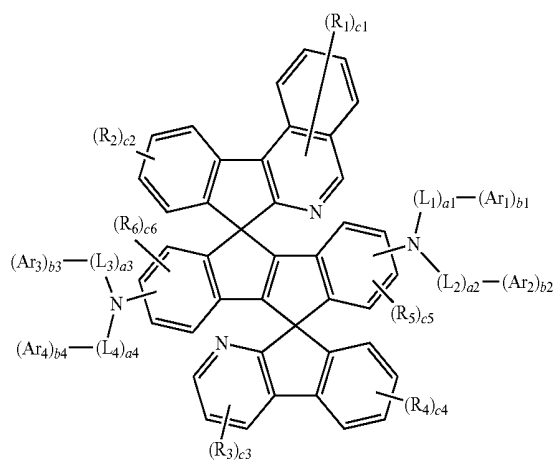
Formula 1(17)



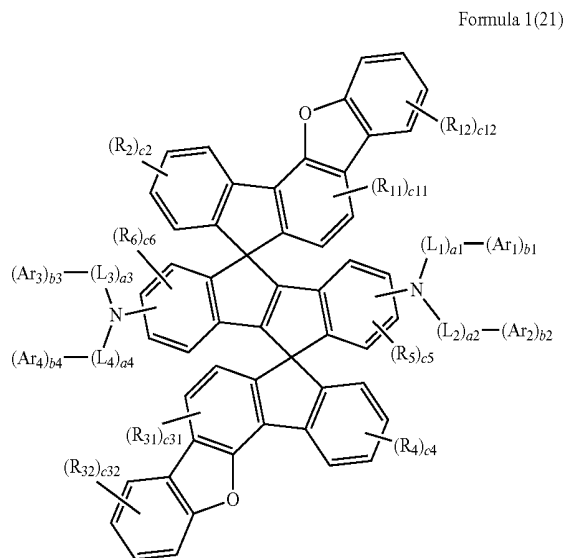
Formula 1(20)



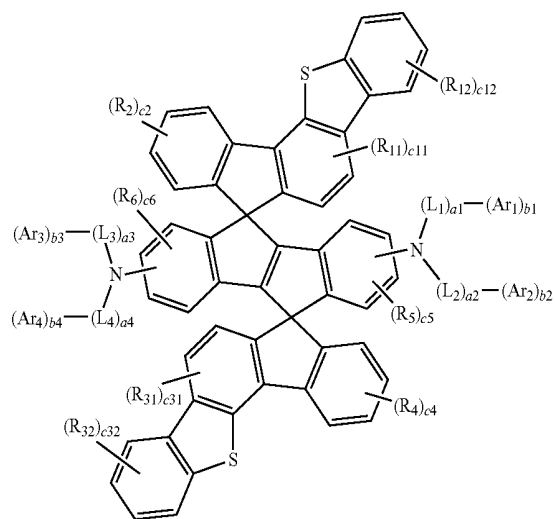
Formula 1(18)



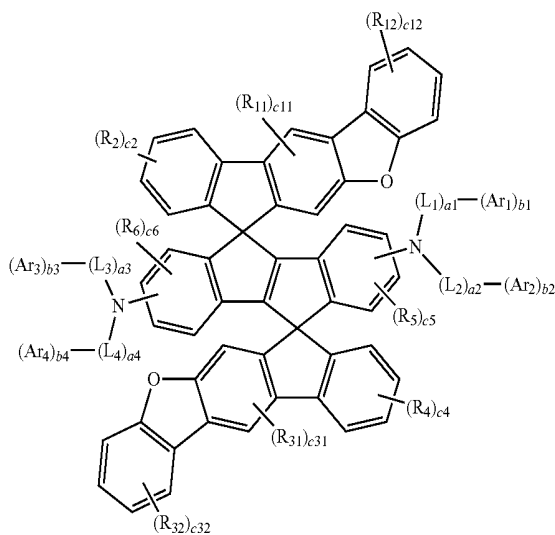
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Formula 1(22)

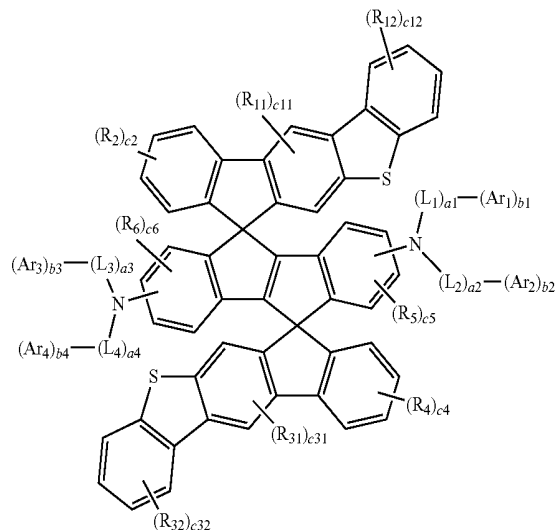


Formula 1(23)

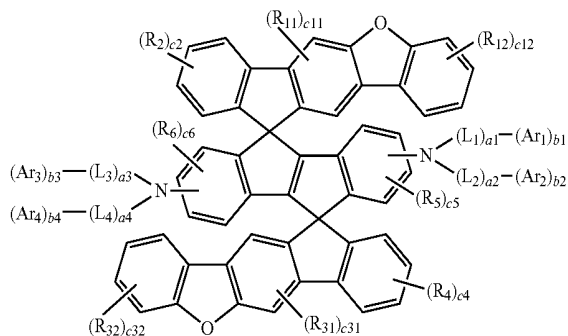


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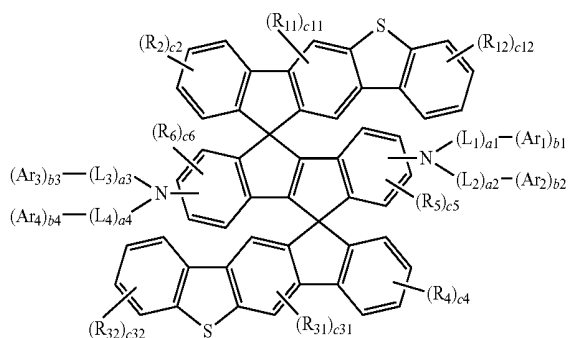
Formula 1(24)



Formula 1(25)



Formula 1(26)



**[0087]** In Formulae 1(1) to 1(18), L<sub>1</sub> to L<sub>4</sub>, a<sub>1</sub> to a<sub>4</sub>, Ar<sub>1</sub> to Ar<sub>4</sub>, b<sub>1</sub> to b<sub>4</sub>, R<sub>1</sub> to R<sub>6</sub>, and c<sub>1</sub> to c<sub>6</sub> may be the same as those described herein.

**[0088]** In Formulae 1(19) and 1(26), L<sub>1</sub> to L<sub>4</sub>, a<sub>1</sub> to a<sub>4</sub>, Ar<sub>1</sub> to Ar<sub>4</sub>, b<sub>1</sub> to b<sub>4</sub>, R<sub>2</sub>, R<sub>4</sub> to R<sub>6</sub>, c<sub>2</sub>, and c<sub>4</sub> to c<sub>6</sub> may be the same as those described herein.

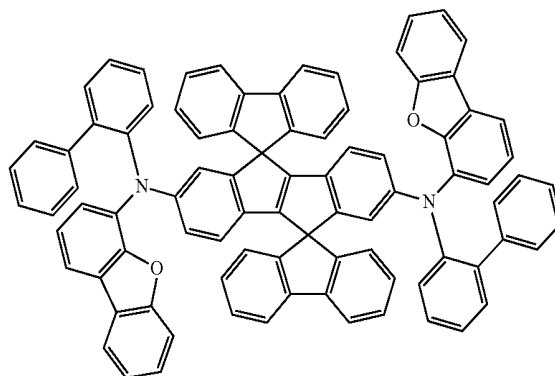
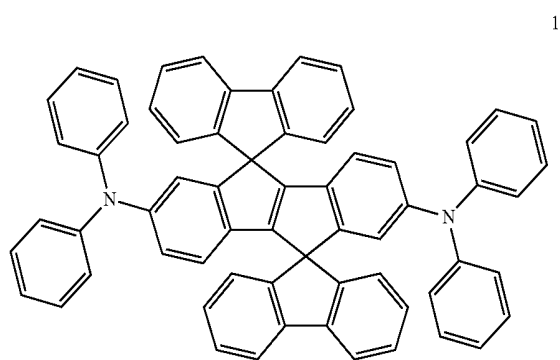
**[0089]** R<sub>11</sub> and R<sub>12</sub>; and R<sub>31</sub> and R<sub>32</sub> may be the same as R<sub>1</sub> and R<sub>3</sub>, respectively.

**[0090]** c<sub>11</sub> and c<sub>31</sub> may each independently be, e.g., an integer of 0 to 2, and c<sub>12</sub> and c<sub>32</sub> may each independently be, e.g., an integer of 0 to 4.

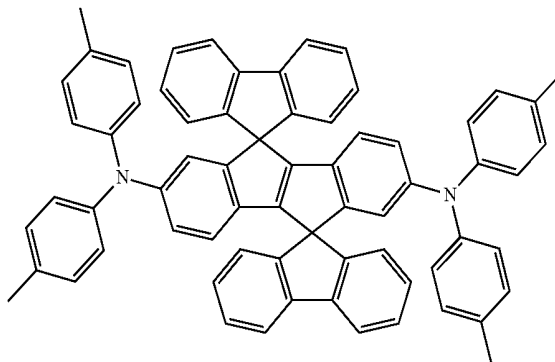
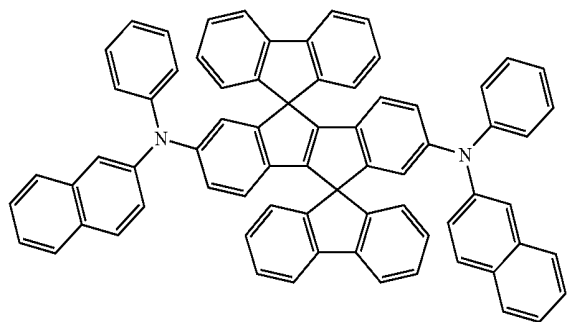
[0091] In an implementation, the condensed-cyclic compound may be one of Compounds 1 to 69.

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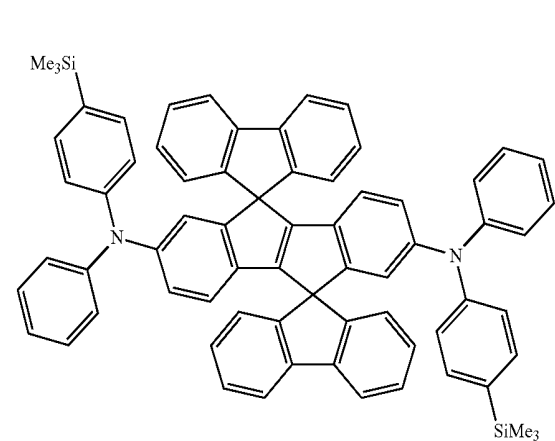
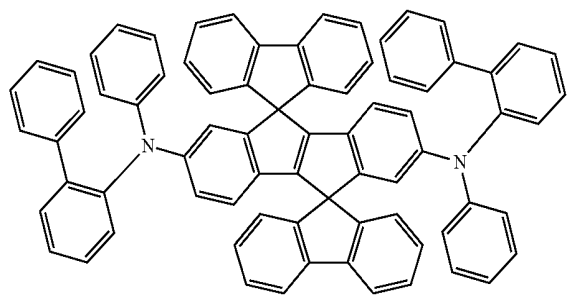
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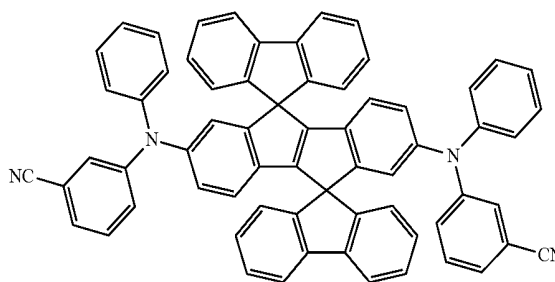
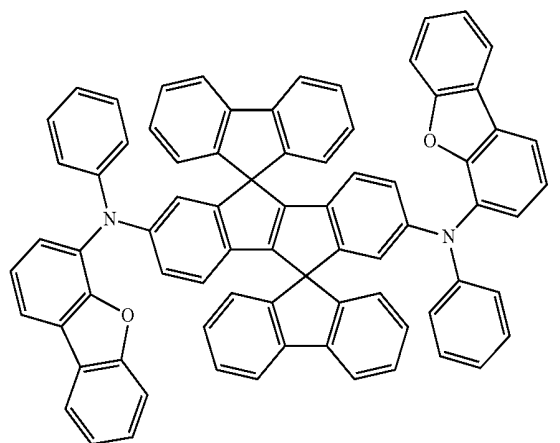
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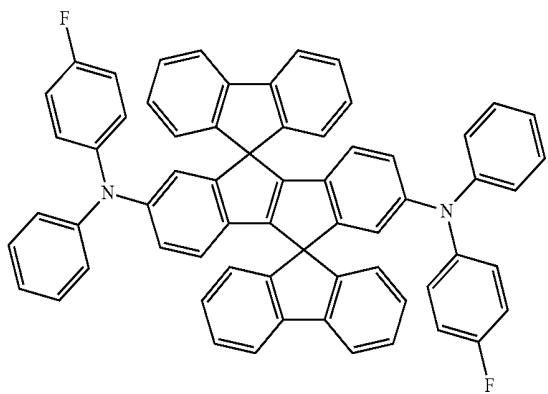


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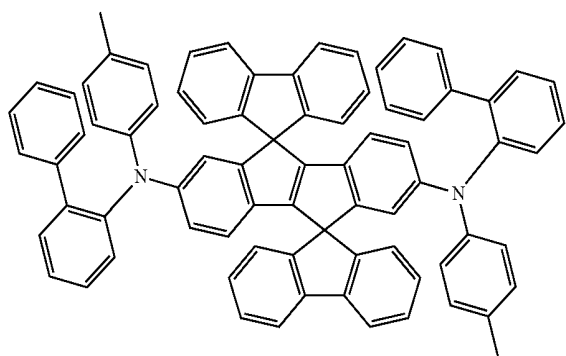


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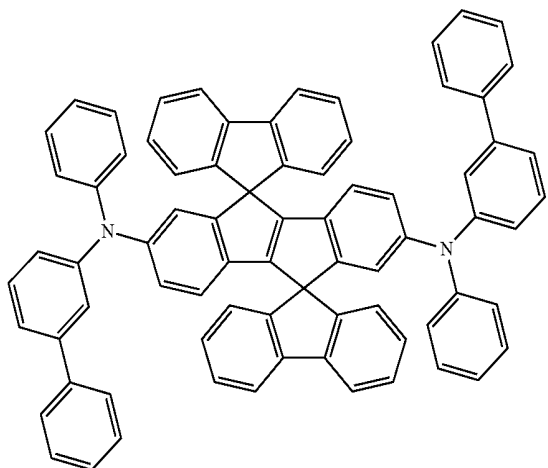
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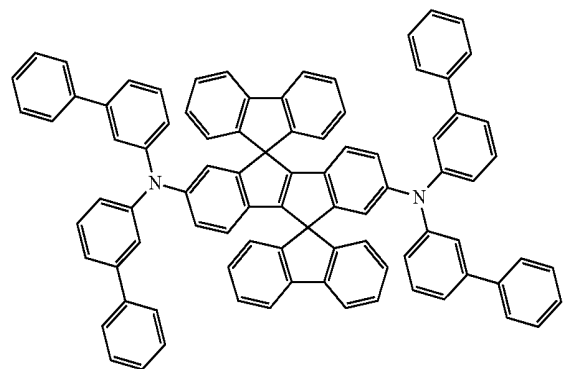
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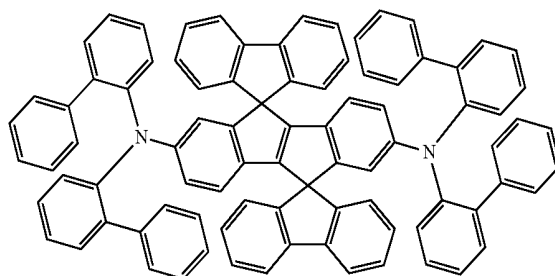


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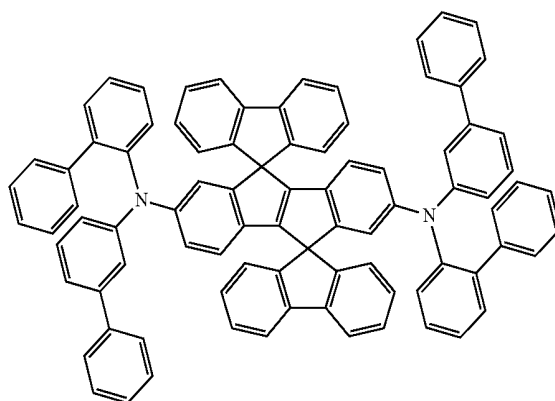


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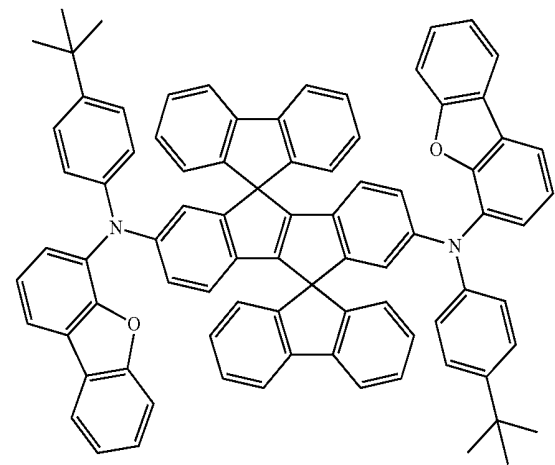
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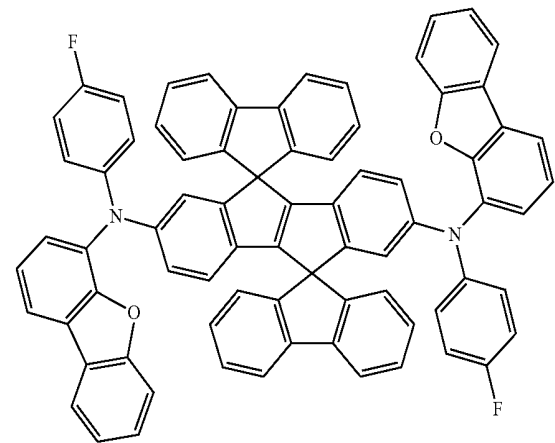
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15



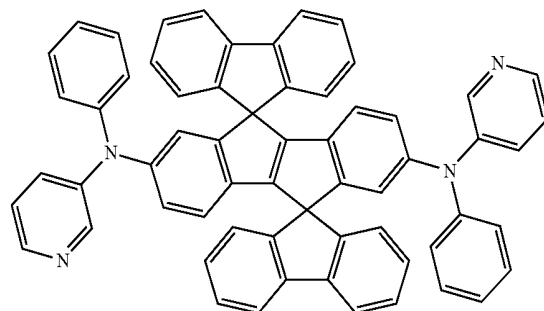
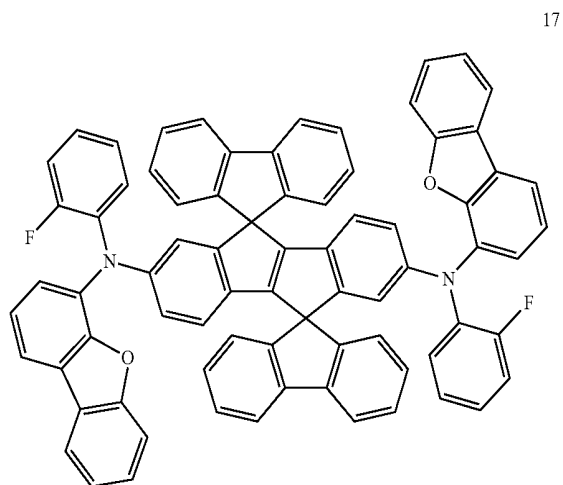
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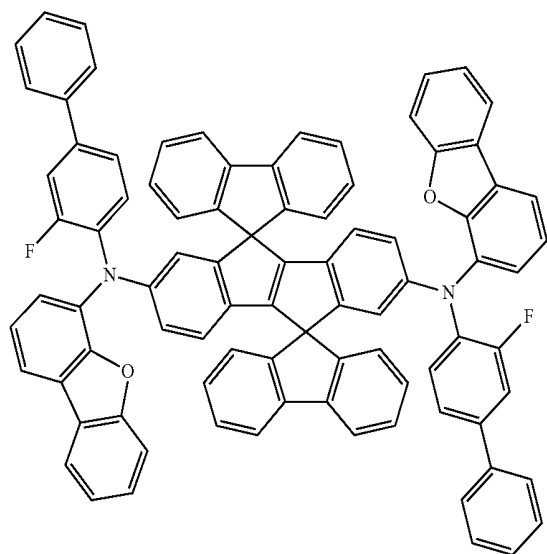
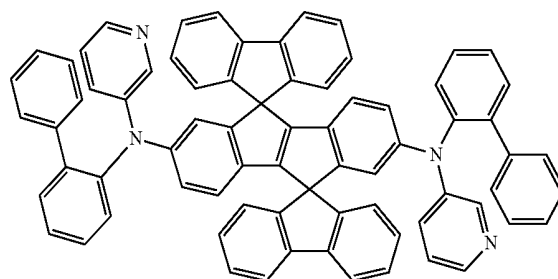
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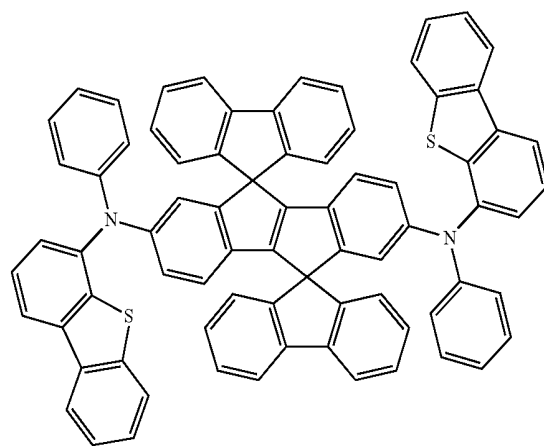
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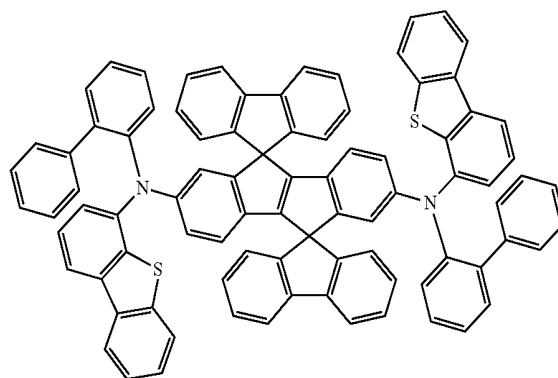
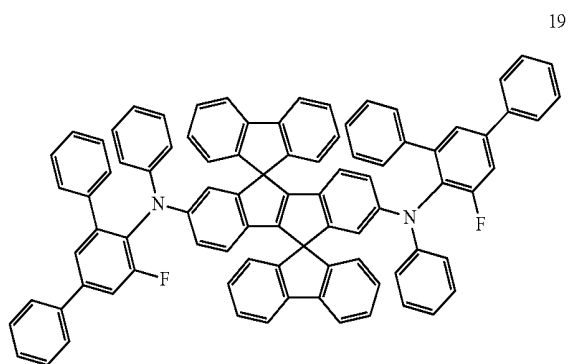
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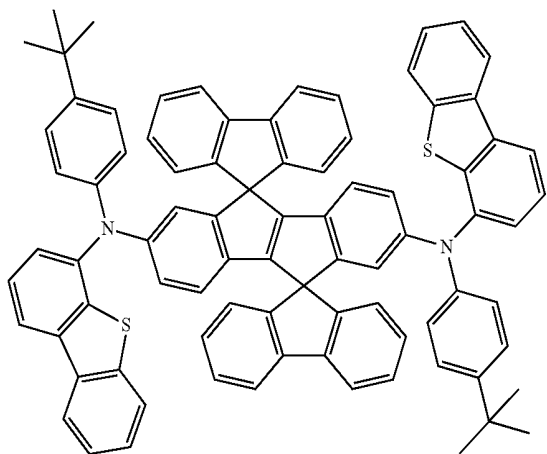


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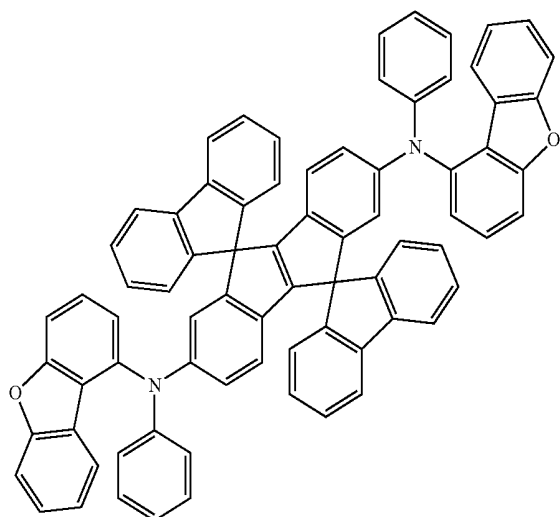


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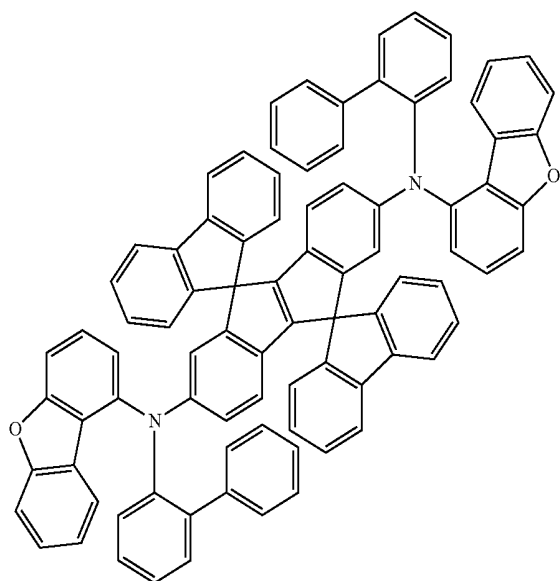
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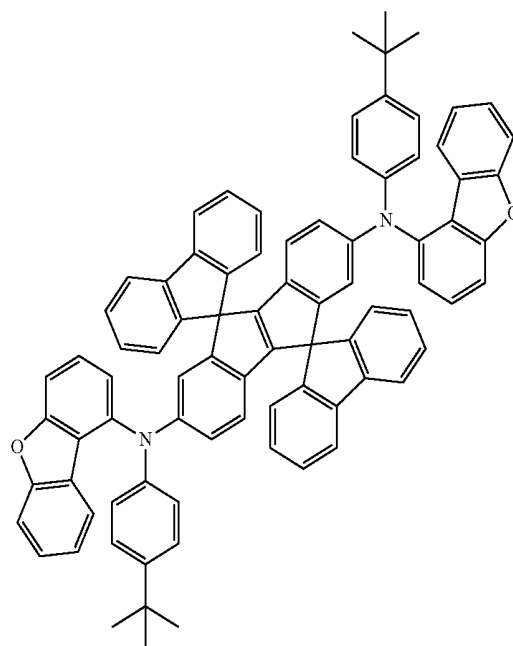


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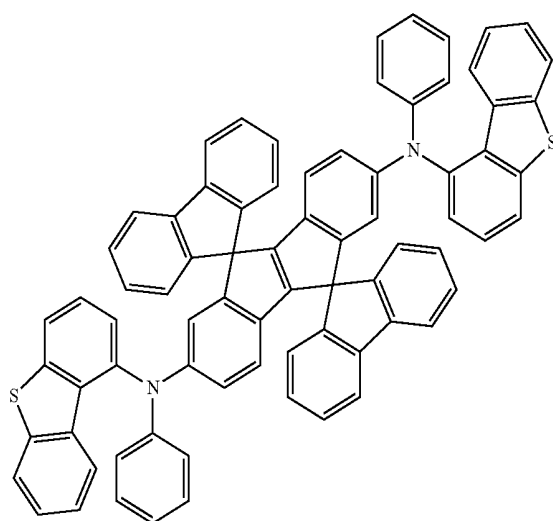


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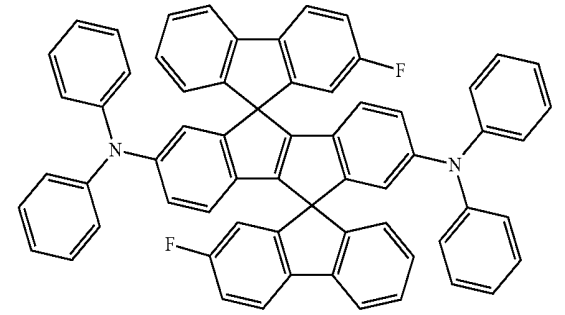
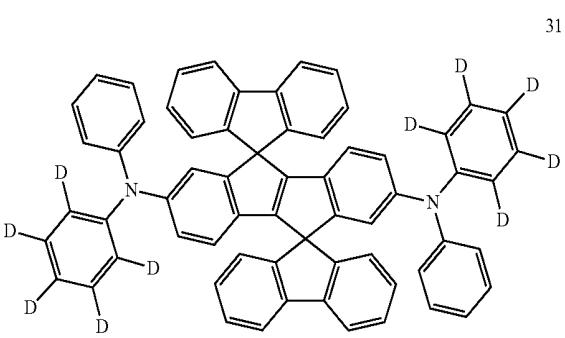
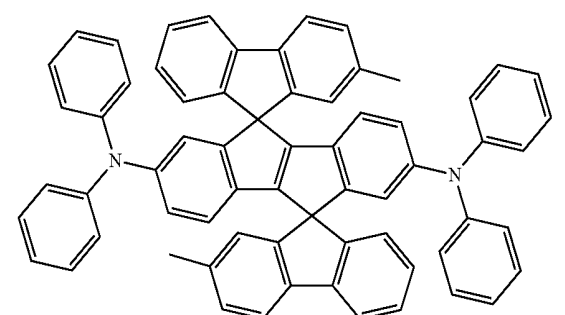
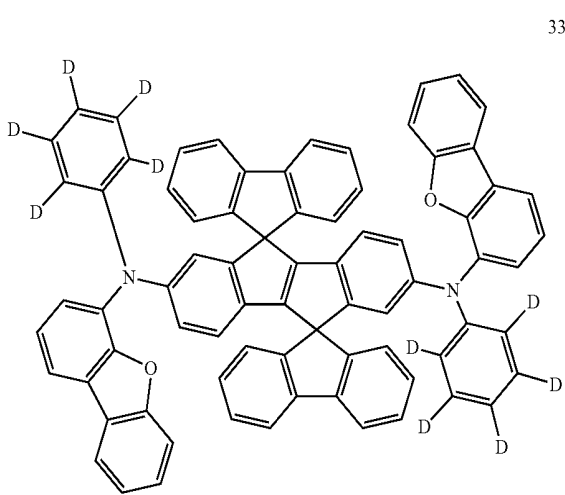
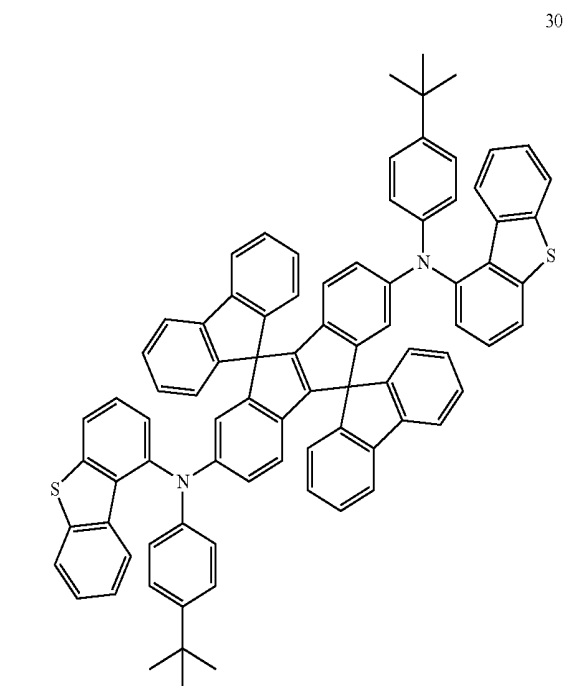
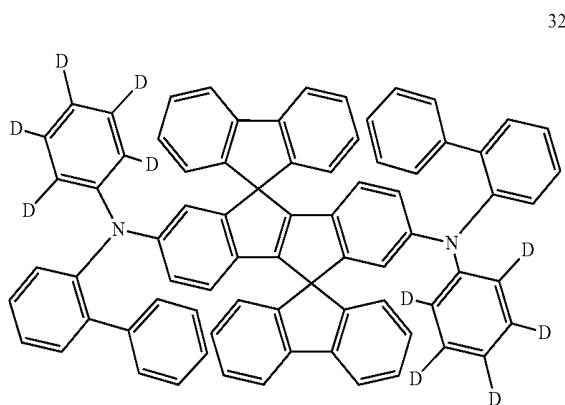
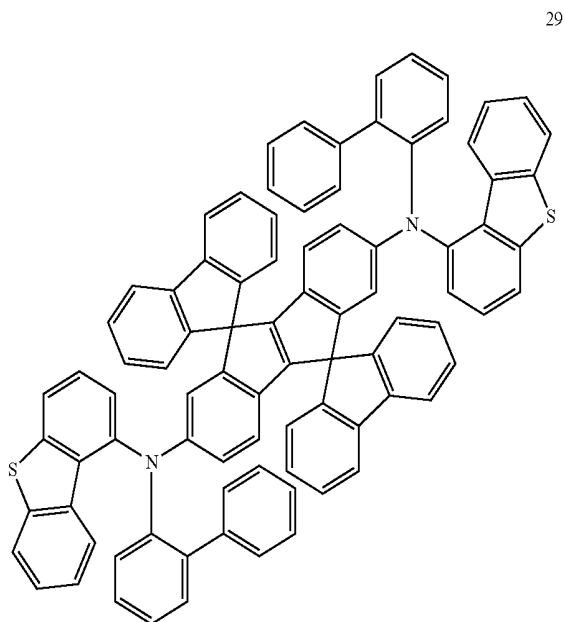


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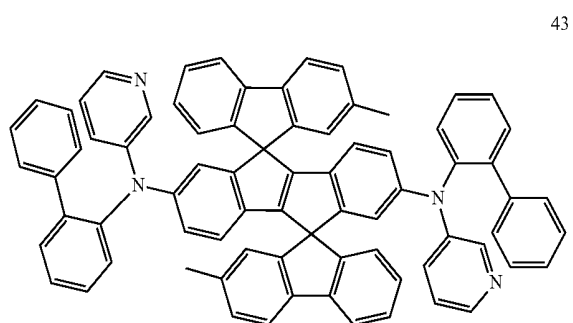
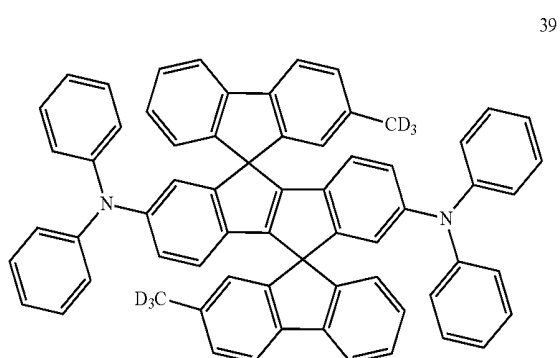
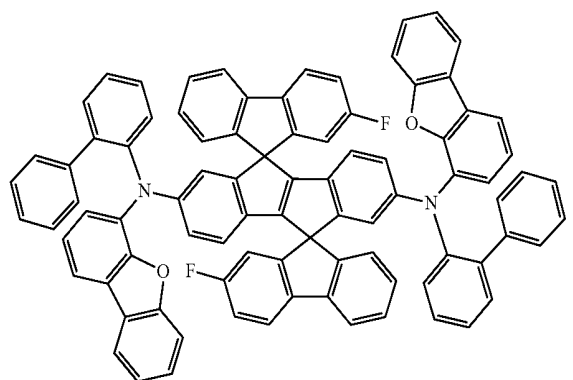
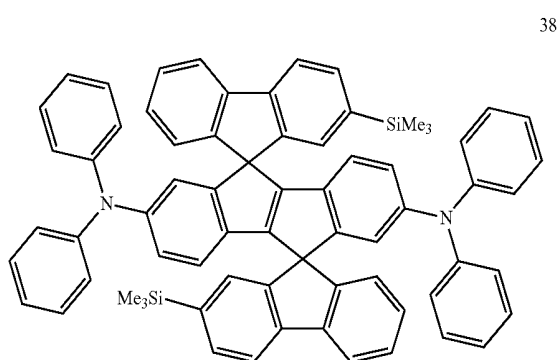
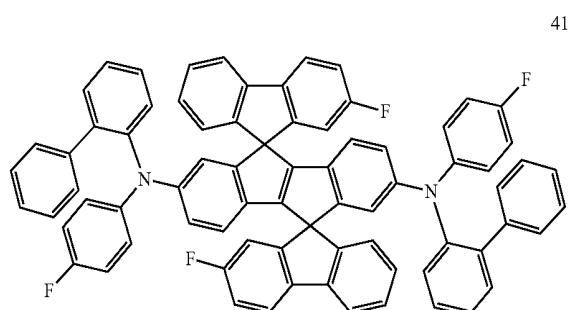
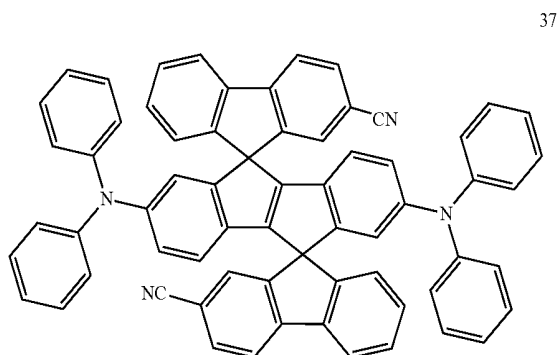
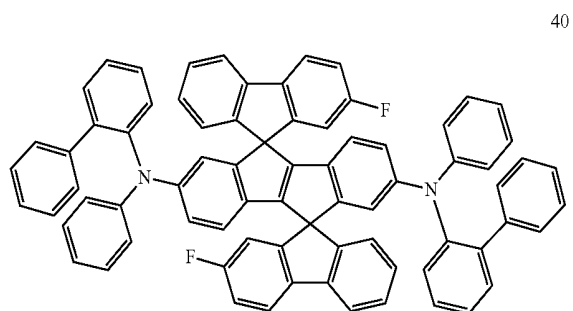
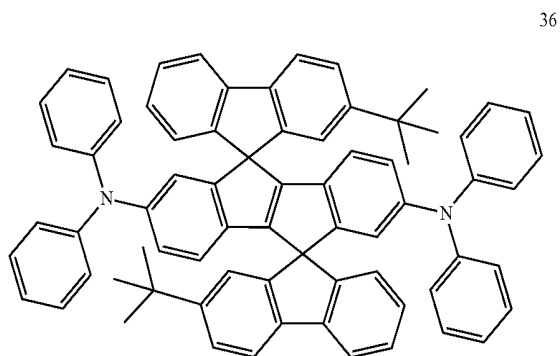
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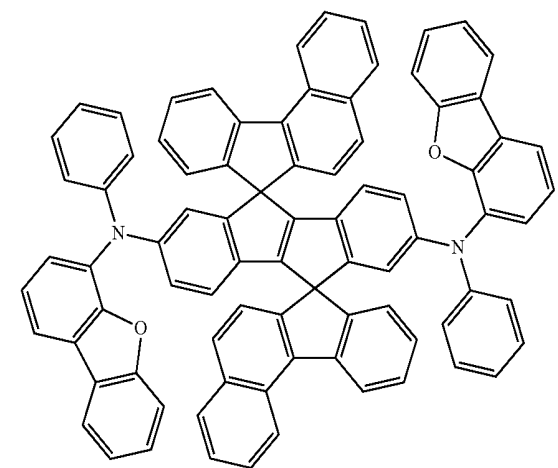
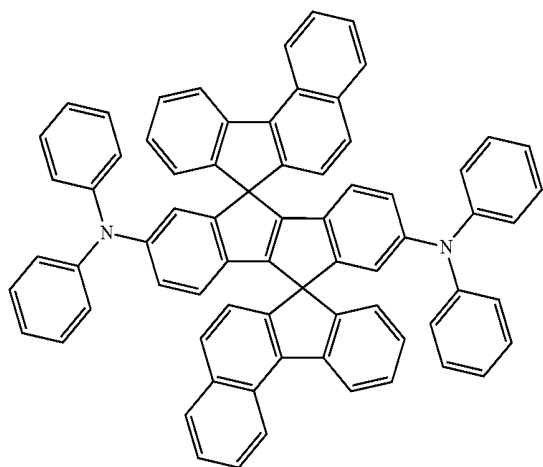
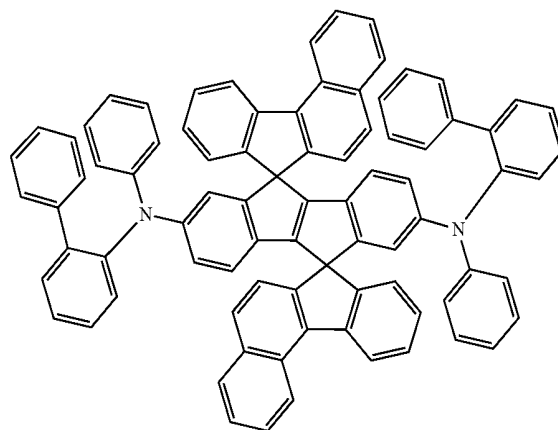
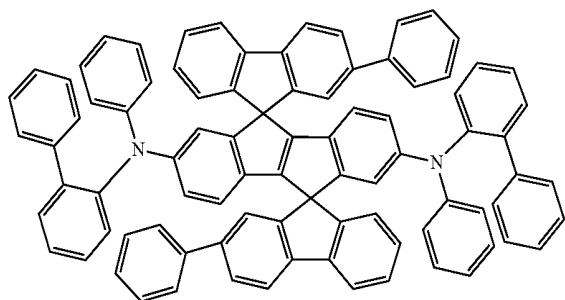
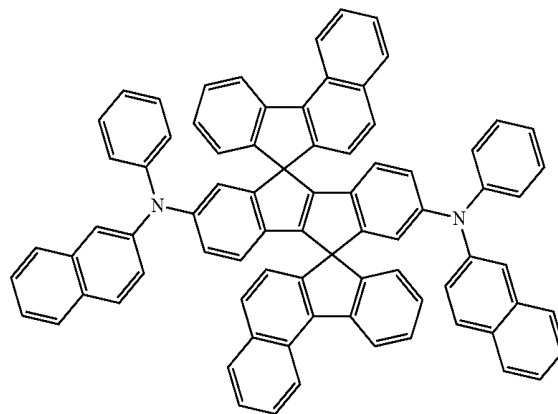
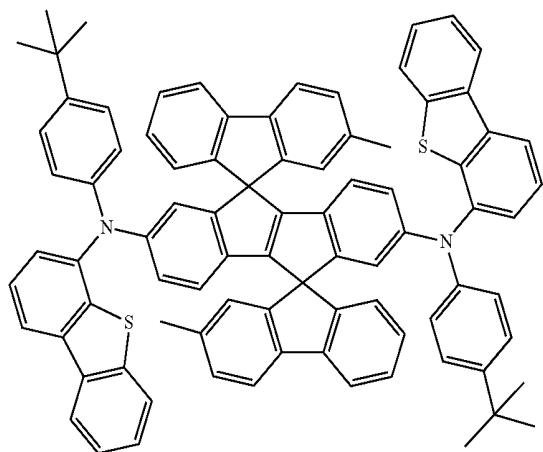
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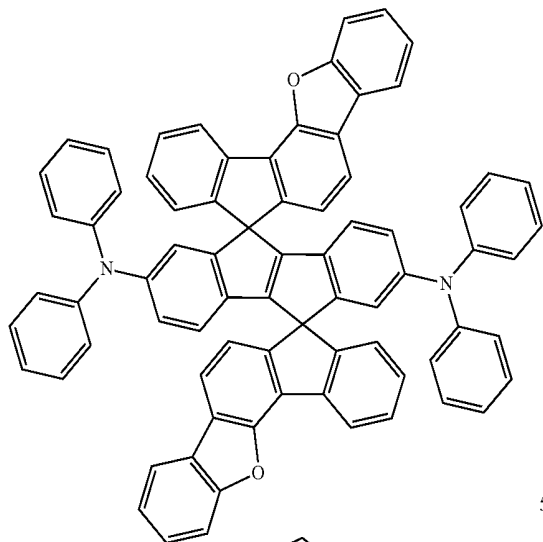
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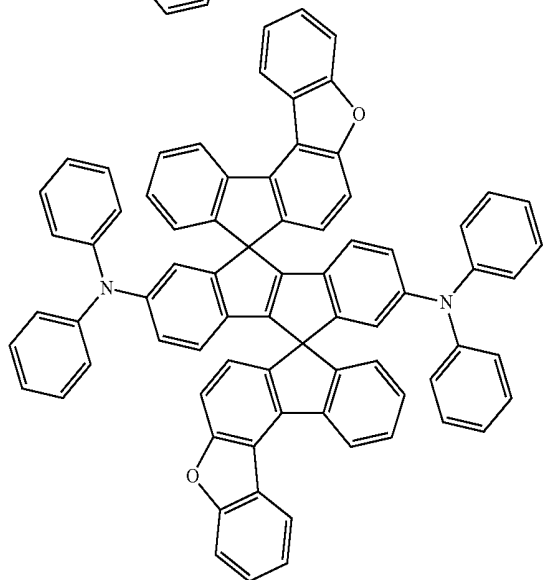


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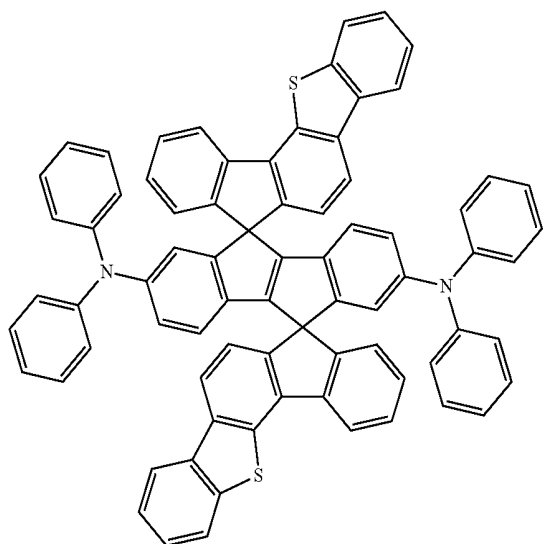
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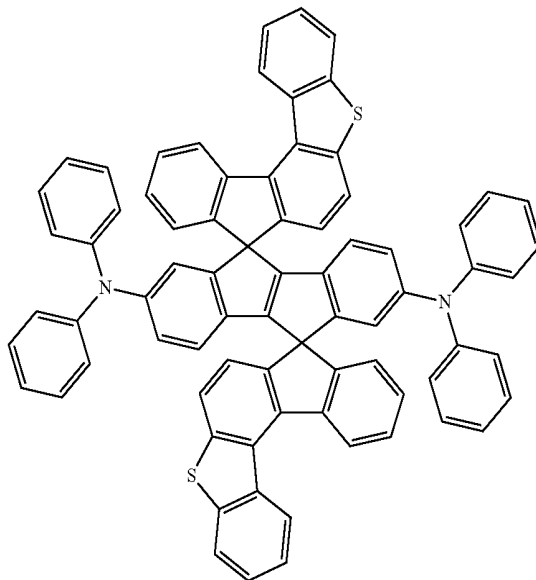


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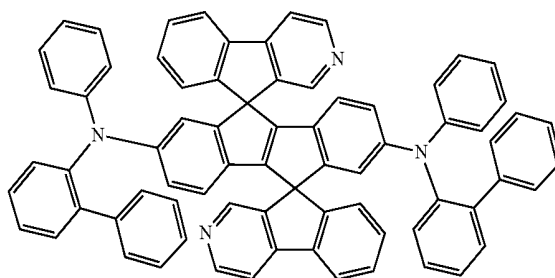


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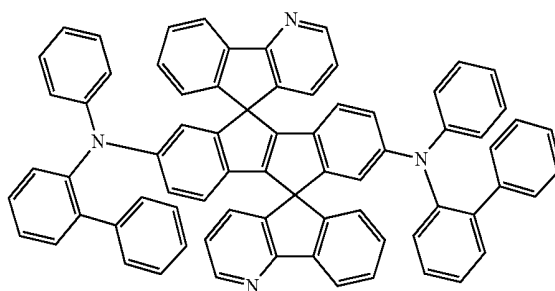
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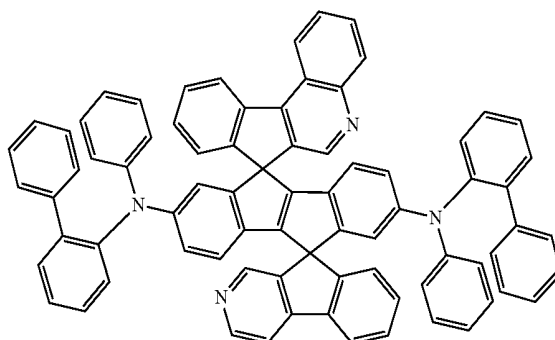
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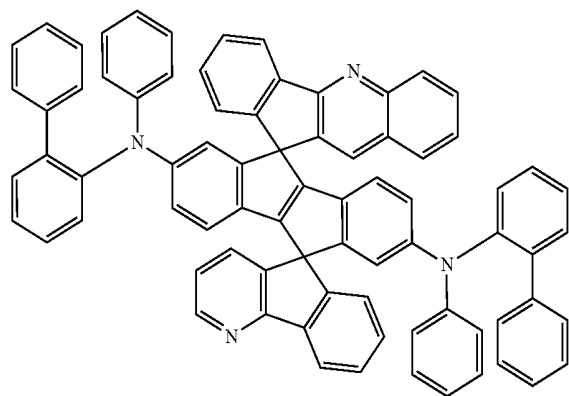
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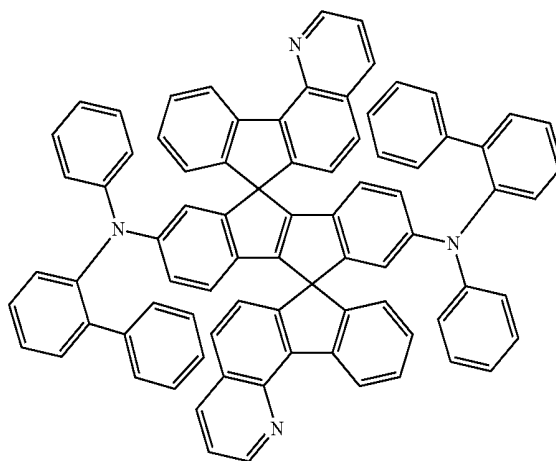


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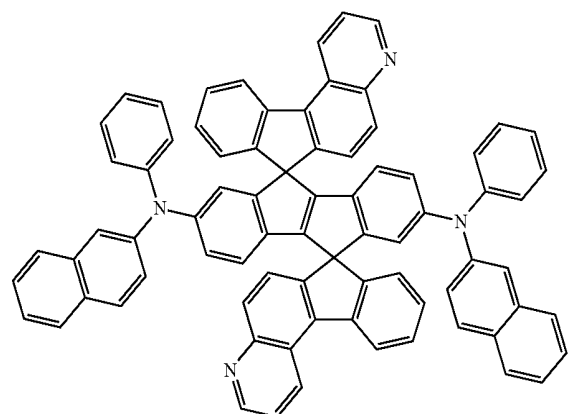


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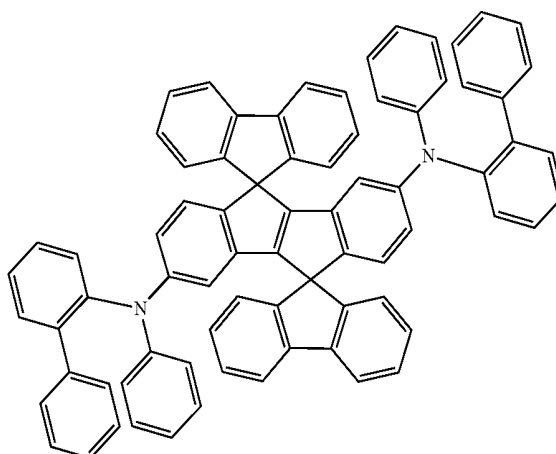
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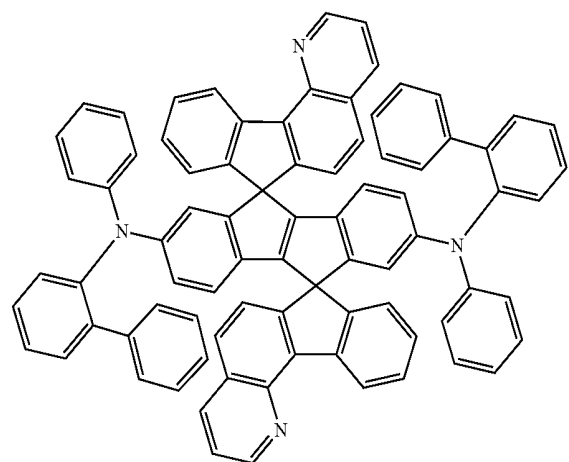
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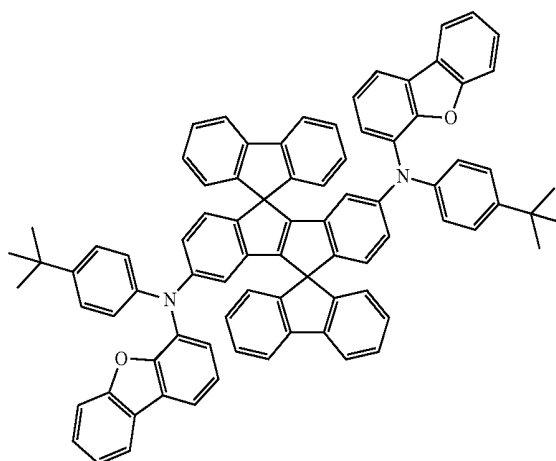
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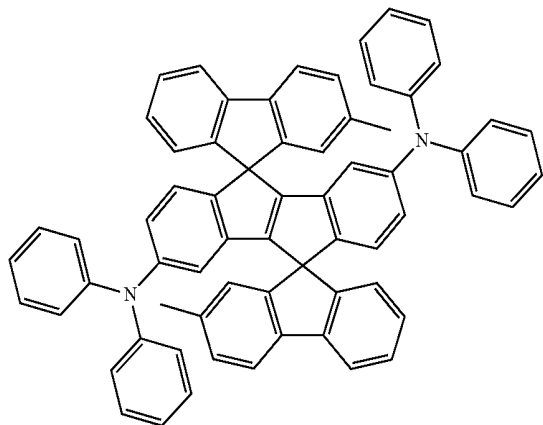


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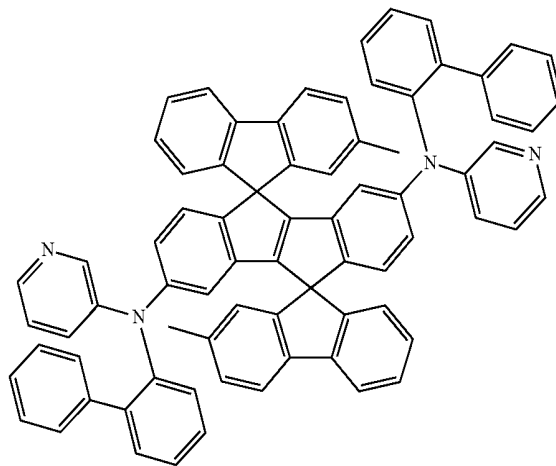
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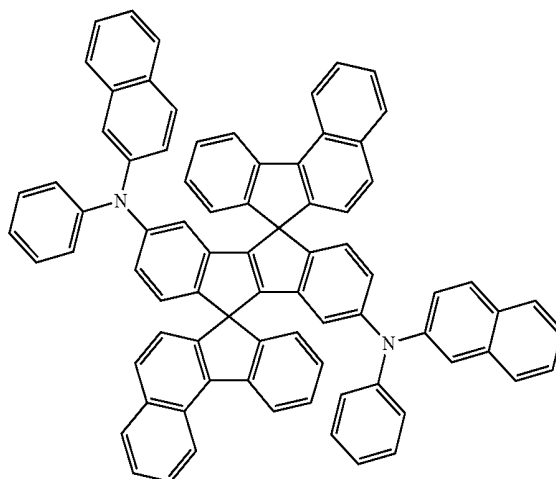
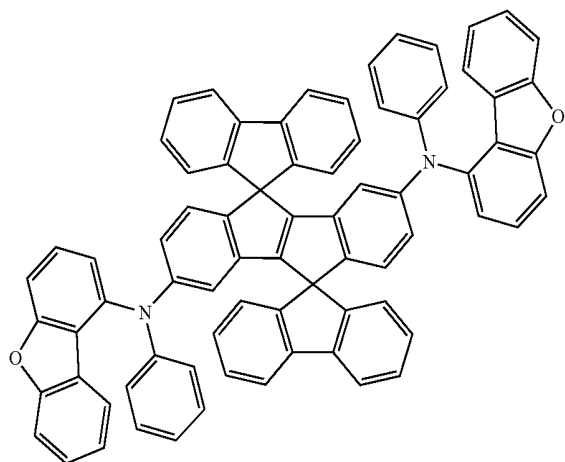
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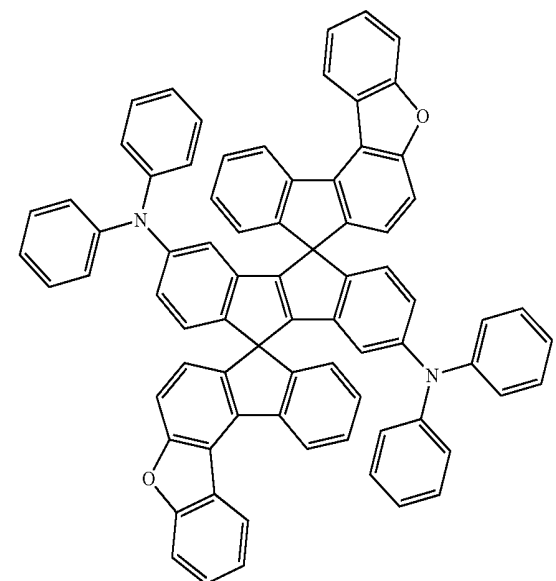
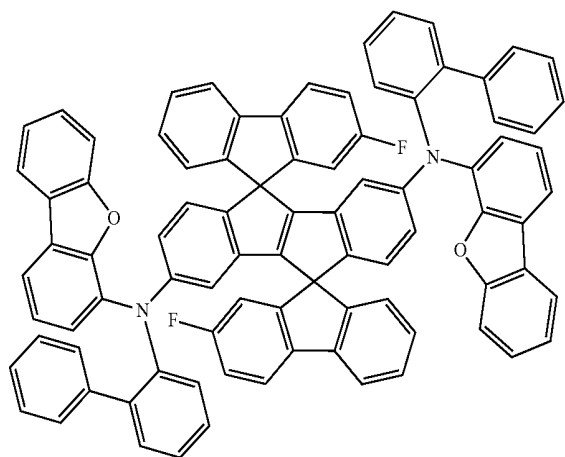
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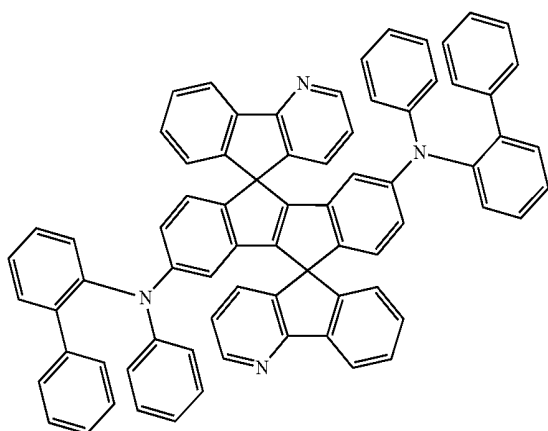
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[0092] The condensed-cyclic compound represented by Formula 1 may have a structure of a spiroindenonindene group to which an arylamine group is directly bound. Due to steric hindrance, the vibronic state of molecules may be reduced, which may lead to a decrease of a full width at half maximum (FWHM) of an emission wavelength. Due to the directly bound amine substituent, the emission efficiency in the molecules may improve, resulting in blue emission with high efficiency.

[0093] The condensed-cyclic compound represented by Formula 1 may include a spiroindenonindene group. For example, the condensed-cyclic compound may have a rigid structure, having excellent durability and thermal stability. Thus, electronic devices, such as organic light-emitting devices, including the condensed-cyclic compound may have a long lifespan.

[0094] The condensed-cyclic compound represented by Formula 1 may include the spiroindenonindene group, and the condensed-cyclic compound may have a relatively bulky structure. Thus, the spiroindenonindene group may help prevent aggregation between the same molecules neighboring to each other. Therefore, when the condensed-cyclic compound is used as an emission material, concentration quenching may be reduced and/or prevented, which may enable an organic light-emitting device including the condensed-cyclic compound to have high efficiency.

[0095] In addition, the condensed-cyclic compound represented by Formula 1 may include a spiro structure introduced to an indenonindene group. For example, the intramolecular vibration and rotation mode in the case of emission may be effectively prevented. Thus, the second shoulder of an emission wavelength may be reduced. Accordingly, an organic light-emitting device including the condensed-cyclic compound may have a FWHM of a narrow emission spectrum, thus exhibiting high efficiency and excellent luminance.

[0096] For example, when a bulky-condensed ring, which may help increase the steric hindrance of a diamine substituent, is introduced to a spiroindenonindene group in the condensed-cyclic compound represented by Formula 1, a more rigid structure may be obtained and also the intermolecular interaction, intramolecular vibration, and rotation mode may be more effectively suppressed. Accordingly, an organic light-emitting device including the condensed-cy-

clitic compound may have enhanced high efficiency, high luminance, and long lifespan.

[0097] Methods of synthesizing the condensed-cyclic compound represented by Formula 1 may be understood by referring to Examples described herein.

[0098] At least one condensed-cyclic compounds represented by Formula 1 may be included between a pair of electrodes in an organic light-emitting device. In an implementation, the condensed-cyclic compound may be included in an emission layer. In an implementation, the condensed-cyclic compound represented by Formula 1 may be used as a material for forming a capping layer, which is disposed on outer sides of a pair of electrodes in an organic light-emitting device.

[0099] Accordingly, there is provided an organic light-emitting device including a first electrode; a second electrode facing the first electrode; and an organic layer disposed between the first electrode and the second electrode. The organic layer may include an emission layer and at least one condensed-cyclic compound represented by Formula 1.

[0100] The expression “(an organic layer) includes at least one condensed-cyclic compound” as used herein refer to an embodiment in which “(an organic layer) includes identical compounds represented by Formula 1 and to an embodiment in which (an organic layer) includes two or more different condensed-cyclic compounds represented by Formula 1.”

[0101] In an implementation, the organic layer may include only Compound 1 as the condensed-cyclic compound. In this case, Compound 1 may be included in an emission layer of the organic light-emitting device. In an implementation, the organic layer may include both Compounds 1 and 2 as the condensed-cyclic compound. In this case, Compounds 1 and 2 both may be included in an emission layer of the organic light-emitting device.

[0102] The organic layer may include, e.g., i) a hole transport region that is between the first electrode (anode) and the emission layer and includes at least one of a hole injection layer, a hole transport layer, a buffer layer, and an electron blocking layer, and ii) an electron transport region that is between the emission layer and the second electrode (cathode) and includes at least one selected from a hole blocking layer, an electron transport layer, and an electron injection layer. In an implementation, the emission layer may include the at least one condensed-cyclic compound represented by Formula 1, and the hole transport layer may include a p-type dopant compound. In an implementation, the emission layer may include the at least one condensed-cyclic compound represented by Formula 1, and the electron transport layer may include an n-type dopant compound. In an implementation, the emission layer may also include an anthracene-based compound.

[0103] In an implementation, the organic light-emitting device may further include at least one of a first capping layer disposed on a pathway through which light emitted from an emission layer proceeds toward the outside through the first electrode; and a second capping layer disposed on a pathway through which light emitted from an emission layer proceeds toward the outside through the second electrode, wherein the at least one of the first capping layer and the second capping layer may include the at least one condensed-cyclic compound.

[0104] In an implementation, an 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, wherein at least one of the first capping layer and the second capping layer may include the at least one condensed-cyclic compound.

[0105] The term “organic layer” as used herein refers to a single layer and/or a plurality of layers disposed between the first electrode and the second electrode of the organic light-emitting device. Materials included in the “organic layer” are not limited to organic materials.

[0106] FIG. 1 illustrates a schematic cross-sectional 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.

[0107] Hereinafter, the structure of an organic light-emitting device and a method of manufacturing an organic light-emitting device, according to an embodiment, will be described in connection with FIG. 1.

[0108] In an implementation, a substrate may be additionally disposed under the first electrode 110 or above the second electrode 190. The substrate may be a glass substrate or a plastic substrate, each having excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and water-resistance.

[0109] 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.

[0110] The first electrode 110 may be a reflective electrode, a semi-transmissive electrode, or a transmissive electrode. When the first electrode 110 is a transmissive electrode, a material for forming the first electrode 110 may be selected from indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO<sub>2</sub>), zinc oxide (ZnO), and any combinations thereof. In an implementation, when the first electrode 110 is a semi-transmissive electrode or a reflective electrode, a material for forming the first electrode 110 may be selected from magnesium (Mg), silver (Ag), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), magnesium-silver (Mg—Ag), and any combinations thereof.

[0111] 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 ITO/Ag/ITO structure.

[0112] The organic layer 150 may be disposed on the first electrode 110. The organic layer 150 may include an emission layer.

[0113] The organic layer 150 may further include a hole transport region between the first electrode 110 and the

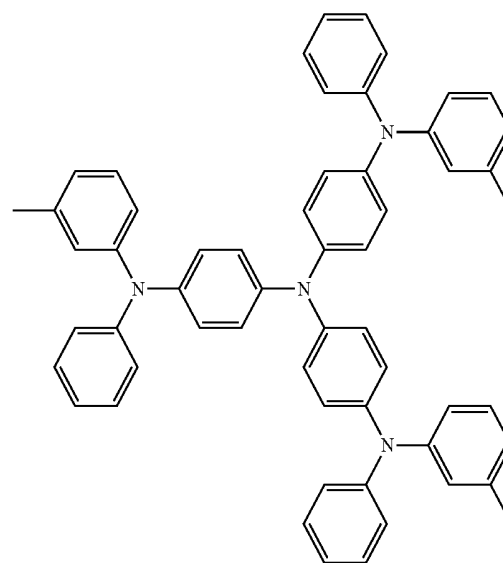
emission layer, and an electron transport region between the emission layer and the second electrode 190.

[0114] 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.

[0115] 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.

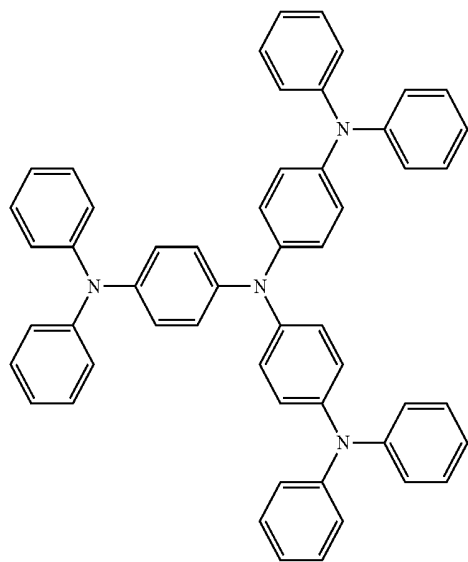
[0116] For example, the hole transport region may have a single-layered structure including a single layer including a plurality of different materials, or a multi-layered structure having a hole injection layer/hole transport layer structure, a hole injection layer/hole transport layer/emission auxiliary 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 layers of each structure are sequentially stacked on the first electrode 110 in each stated order.

[0117] The hole transport region may include at least one selected from m-MTDATA, TDATA, 2-TNATA, NPB (NPB), β-NPB, TPD, Spiro-TPD, Spiro-NPB, methylated-NPB, TAPC, HMTPD, 4,4',4''-tris(N-carbazolyl)triphenylamine (TCTA), polyaniline/dodecylbenzenesulfonic acid (PANI/DBSA), poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate) (PEDOT/PSS), polyaniline/camphor sulfonic acid (PANI/CSA), polyaniline/poly(4-styrenesulfonate) (PANI/PSS), a compound represented by Formula 201, and a compound represented by Formula 202:

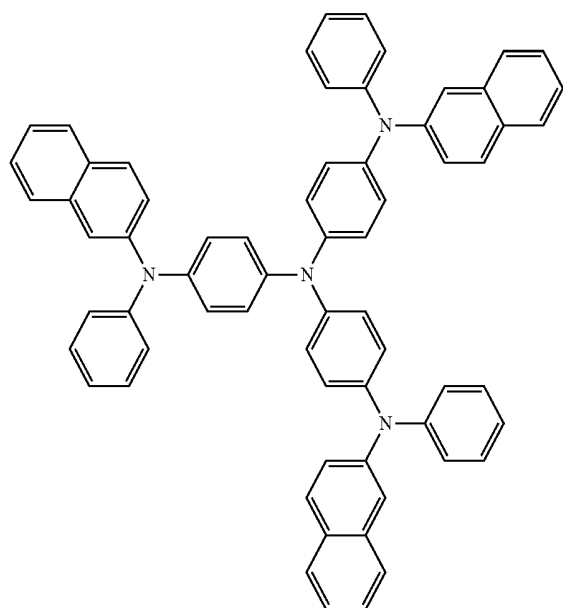


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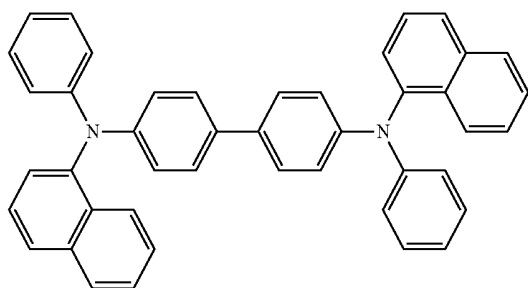
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TDATA

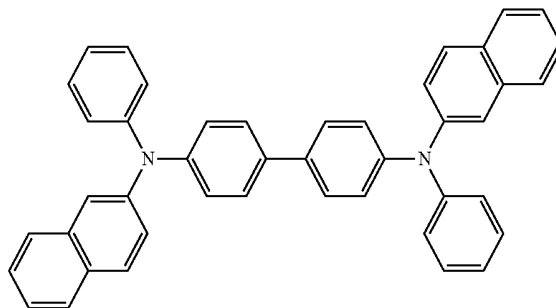


2-TNATA

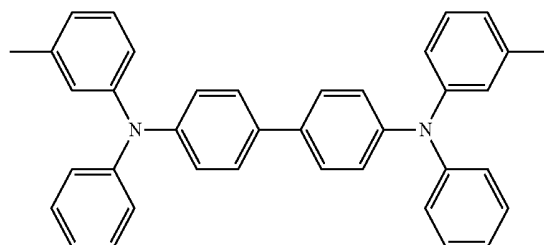


NPB

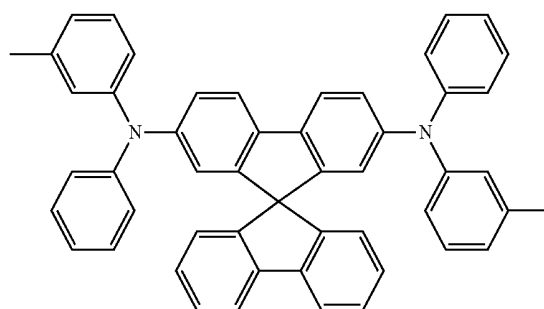
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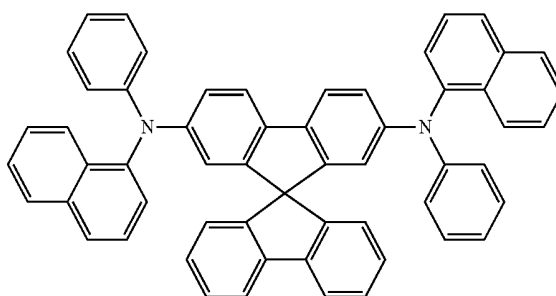
$\beta$ -NPB



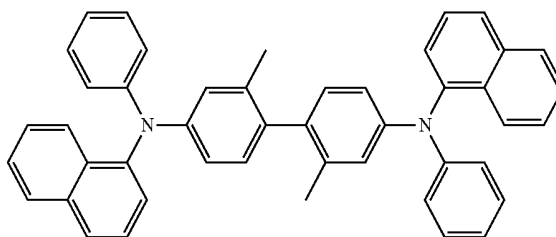
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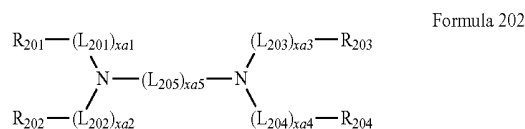
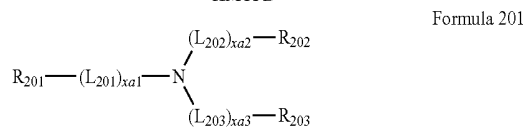
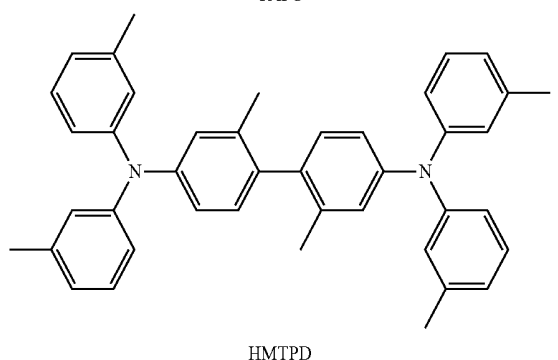
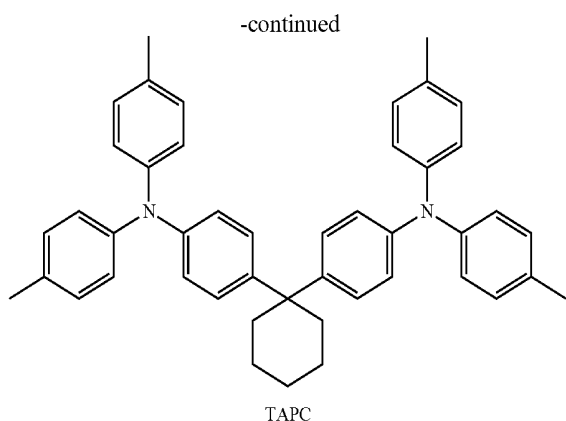
Spiro-TPD



Spiro-NPB



methylated NPB



[0118] wherein, in Formulae 201 and 202,

[0119]  $L_{201}$  to  $L_{204}$  may each independently be selected from a substituted or unsubstituted  $C_3$ - $C_{10}$  cycloalkylene group, a substituted or unsubstituted  $C_1$ - $C_{10}$  heterocycloalkylene group, a substituted or unsubstituted  $C_3$ - $C_{10}$  cycloalkenylene group, a substituted or unsubstituted  $C_1$ - $C_{10}$  heterocycloalkenylene group, a substituted or unsubstituted  $C_6$ - $C_{60}$  arylene group, a substituted or unsubstituted  $C_1$ - $C_{60}$  heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0120]  $L_{205}$  may be selected from  $*-O-*$ ,  $*-S-*$ ,  $*-N(Q_{201})-*$ , a substituted or unsubstituted  $C_1$ - $C_{20}$  alkylene group, a substituted or unsubstituted  $C_2$ - $C_{20}$  alkenylene group, a substituted or unsubstituted  $C_3$ - $C_{10}$  cycloalkylene group, a substituted or unsubstituted  $C_1$ - $C_{10}$  heterocycloalkylene group, a substituted or unsubstituted  $C_3$ - $C_{10}$  cycloalkenylene group, a substituted or unsubstituted  $C_1$ - $C_{10}$  heterocycloalkenylene group, a substituted or unsubstituted  $C_6$ - $C_{60}$  arylene group, a substituted or unsubstituted  $C_1$ - $C_{60}$  heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0121]  $xa_1$  to  $xa_4$  may each independently be an integer of 0 to 3,

[0122]  $xa_5$  may be an integer of 1 to 10, and

[0123]  $R_{201}$  to  $R_{204}$  and  $Q_{201}$  may each independently be selected from a substituted or unsubstituted  $C_3$ - $C_{10}$  cycloalkyl group, a substituted or unsubstituted  $C_1$ - $C_{10}$  heterocycloalkyl group, a substituted or unsubstituted  $C_3$ - $C_{10}$  cycloalkenyl group, a substituted or unsubstituted  $C_1$ - $C_{10}$  heterocycloalkenyl group, a substituted or unsubstituted  $C_6$ - $C_{60}$  aryl group, a substituted or unsubstituted  $C_6$ - $C_{60}$  aryloxy group, a substituted or unsubstituted  $C_6$ - $C_{60}$  arylthio group, a substituted or unsubstituted  $C_1$ - $C_{60}$  heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group.

[0124] In some embodiments, in Formula 202,  $R_{201}$  and  $R_{202}$  may optionally be bound via a single bond, a dimethyl-methylene group, or a diphenyl-methylene group, and  $R_{203}$  and  $R_{204}$  may optionally be bound via a single bond, a dimethyl-methylene group, or a diphenyl-methylene group.

[0125] In one embodiment, in Formulae 201 and 202,  $L_{201}$  to  $L_{205}$  may each independently be selected from

[0126] a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylenylene group, a heptalenylene group, an indacenylene group, an acenaphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene 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, a dibenzosilolylenylene group, and a pyridinylenylene group; and

[0127] a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylenylene group, a heptalenylene group, an indacenylene group, an acenaphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene 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, a dibenzosilolylenylene group, and a pyridinylenylene group, each substituted with at least one selected from deuterium,  $-F$ ,  $-Cl$ ,  $-Br$ ,  $-I$ , a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a  $C_1$ - $C_{20}$  alkyl group, a  $C_1$ - $C_{20}$  alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group,

a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C<sub>1</sub>-C<sub>10</sub> alkyl group, a phenyl group substituted with —F, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, —Si(Q<sub>31</sub>)(Q<sub>32</sub>)(Q<sub>33</sub>), and —N(Q<sub>31</sub>)(Q<sub>32</sub>),

[0128] wherein Q<sub>31</sub> to Q<sub>33</sub> may each independently be selected from a C<sub>1</sub>-C<sub>10</sub> alkyl group, a C<sub>1</sub>-C<sub>10</sub> alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0129] In one or more embodiments, xa1 to xa4 may each independently be 0, 1, or 2.

[0130] According to another embodiment, xa5 may be 1, 2, 3, or 4.

[0131] In one or more embodiments, R<sub>201</sub> to R<sub>204</sub> and Q<sub>201</sub> may each independently be selected from a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group; and

[0132] a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a

C<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>1</sub>-C<sub>20</sub> 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<sub>1</sub>-C<sub>10</sub> alkyl group, a phenyl group substituted with —F, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, —Si(Q<sub>31</sub>)(Q<sub>32</sub>)(Q<sub>33</sub>), and —N(Q<sub>31</sub>)(Q<sub>32</sub>),

[0133] wherein descriptions of Q<sub>31</sub> to Q<sub>33</sub> may be the same as descriptions thereof provided herein.

[0134] In one or more embodiments, at least one selected from R<sub>201</sub> to R<sub>203</sub> in Formula 201 may be selected from

[0135] a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

[0136] a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>1</sub>-C<sub>20</sub> 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<sub>1</sub>-C<sub>10</sub> alkyl group, a phenyl group substituted with —F, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, but embodiments are not limited thereto.

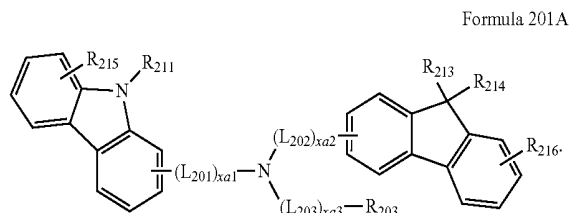
[0137] In one or more embodiments, in Formula 202, i) R<sub>201</sub> and R<sub>202</sub> may be bound via a single bond, and/or ii) R<sub>203</sub> and R<sub>204</sub> may be bound via a single bond.

[0138] In one or more embodiments, at least one selected from R<sub>201</sub> to R<sub>204</sub> in Formula 202 may be selected from

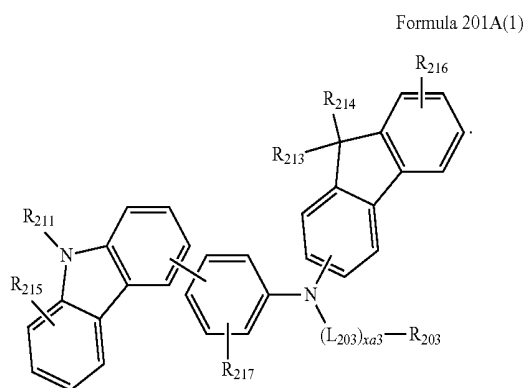
[0139] a carbazolyl group; and

[0140] a carbazolyl group substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>1</sub>-C<sub>20</sub> 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<sub>1</sub>-C<sub>10</sub> alkyl group, a phenyl group substituted with —F, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, but embodiments are not limited thereto.

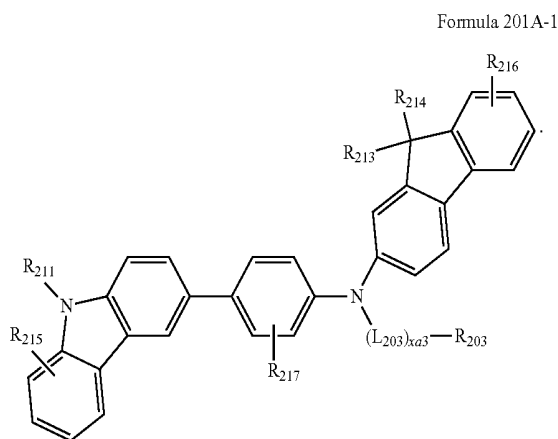
[0141] The compound represented by Formula 201 may be represented by Formula 201A:



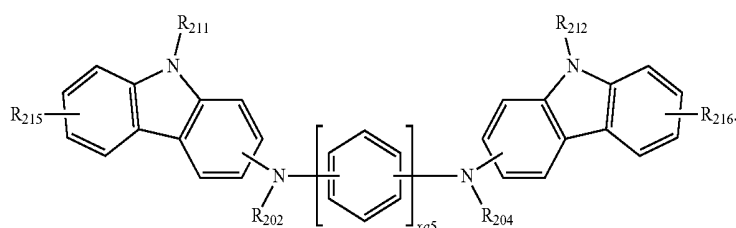
[0142] In some embodiments, the compound represented by Formula 201 may be represented by Formula 201A(1).



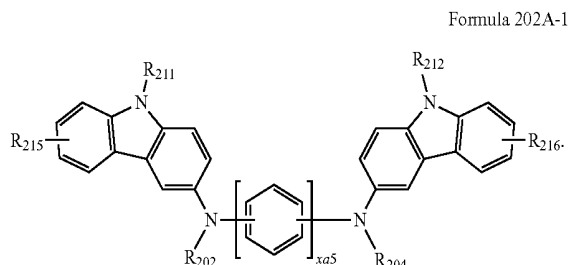
[0143] In some embodiments, the compound represented by Formula 201 may be represented by Formula 201A-1.



[0144] In some embodiments, the compound represented by Formula 202 may be represented by Formula 202A:



[0145] In some embodiments, the compound represented by Formula 202 may be represented by Formula 202A-1:



[0146] In Formulae 201A, 201A(1), 201A-1, 202A, and 202A-1,

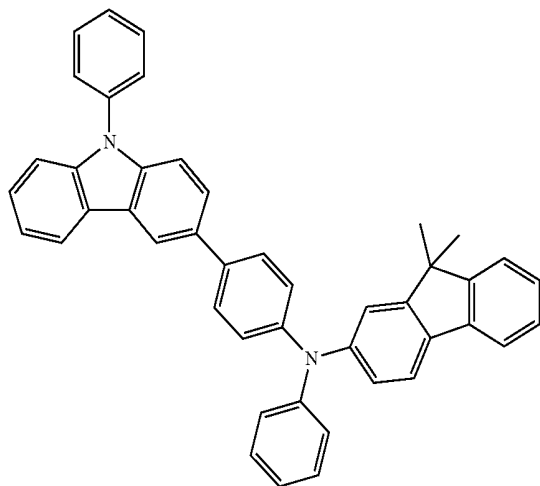
[0147] descriptions of  $L_{201}$  to  $L_{203}$ ,  $xa1$  to  $xa3$ ,  $xa5$ , and  $R_{202}$  to  $R_{204}$  may each independently be the same as descriptions thereof provided herein,

[0148] descriptions of  $R_{211}$  and  $R_{212}$  may each independently be the same as the description provided herein in connection with  $R_{203}$ , and

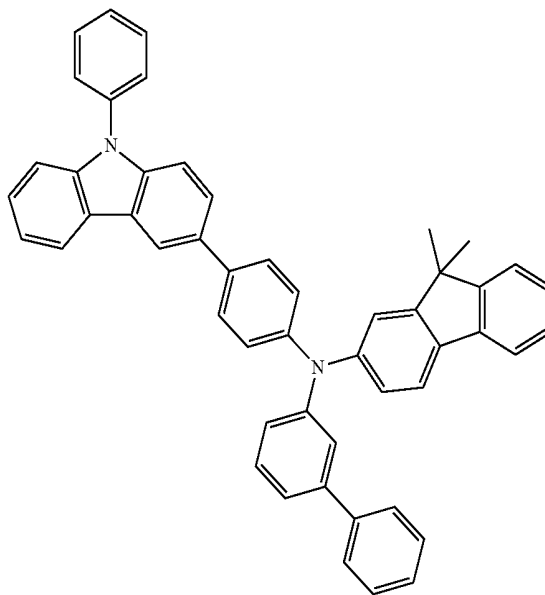
[0149]  $R_{213}$  to  $R_{217}$  may each independently be selected from hydrogen, deuterium,  $-F$ ,  $-Cl$ ,  $-Br$ ,  $-I$ , a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a  $C_1$ - $C_{20}$  alkyl group, a  $C_1$ - $C_{20}$  alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a  $C_1$ - $C_{10}$  alkyl group, a phenyl group substituted with  $-F$ , a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranlyl group, a benzothiophenyl group, a dibenzofuranlyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group.

[0150] The hole transport region may include at least one compound selected from Compounds HT1 to HT39.

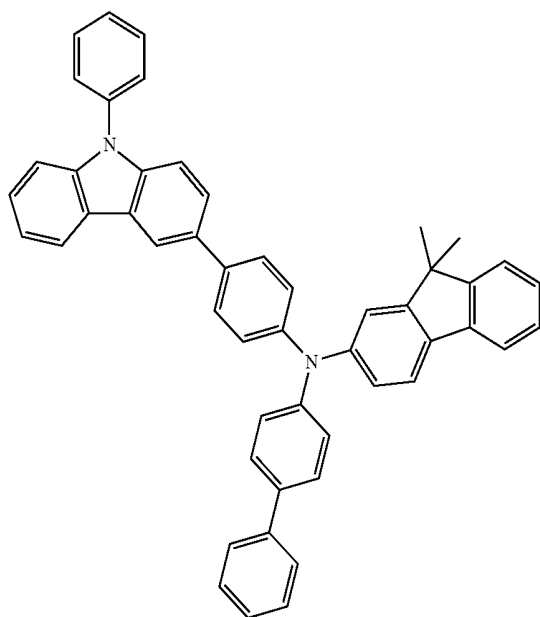
HT1



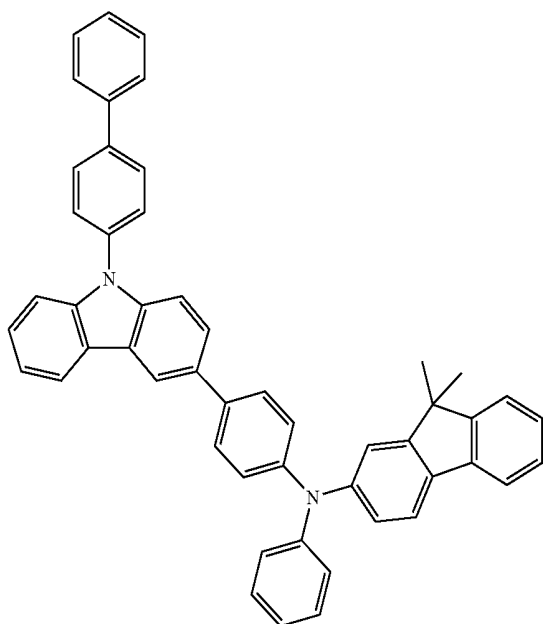
HT2



HT3

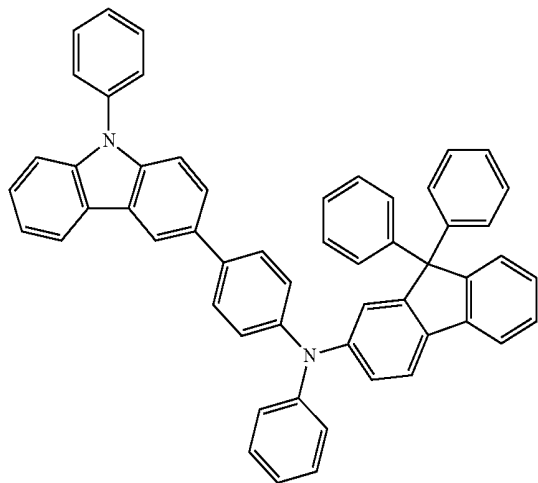


HT4

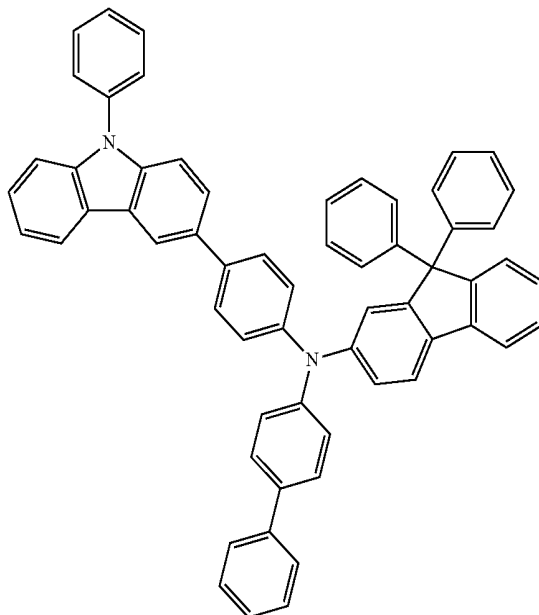


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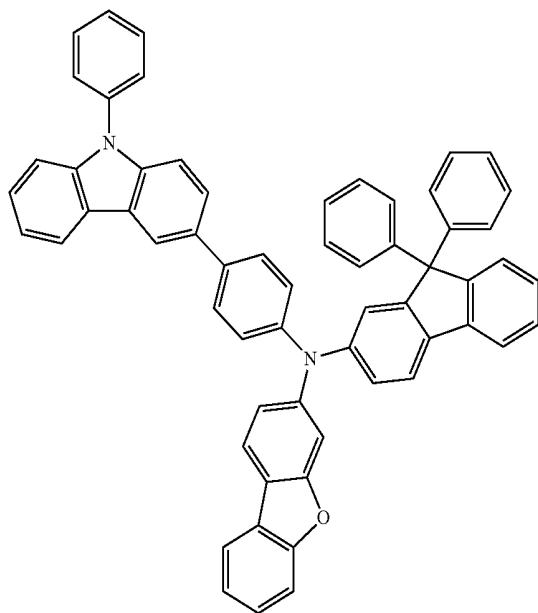
HT5



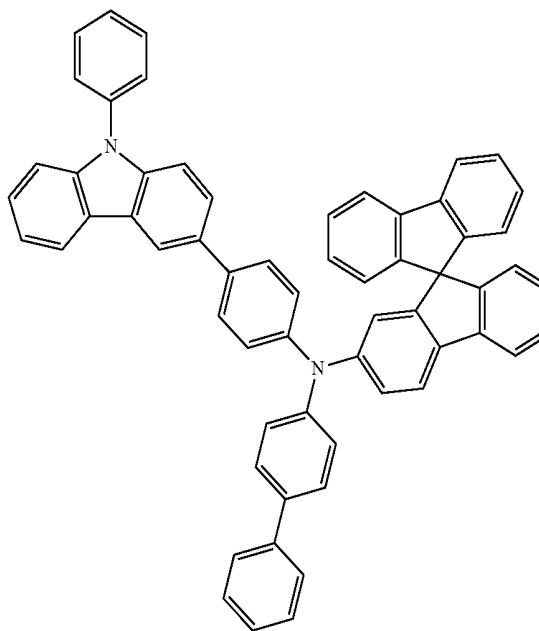
HT6



HT7

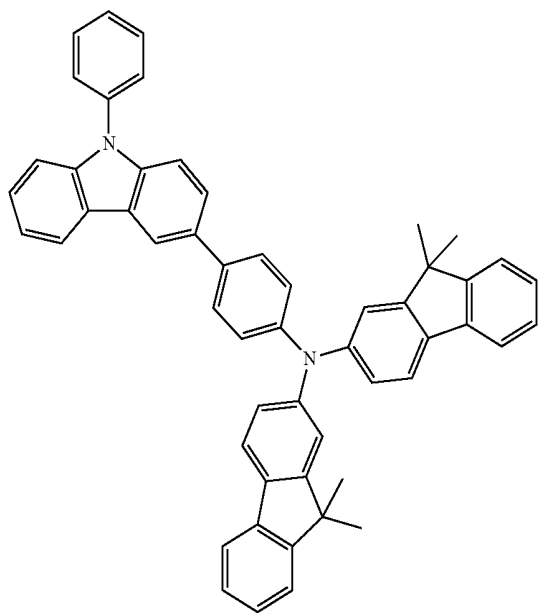


HT8

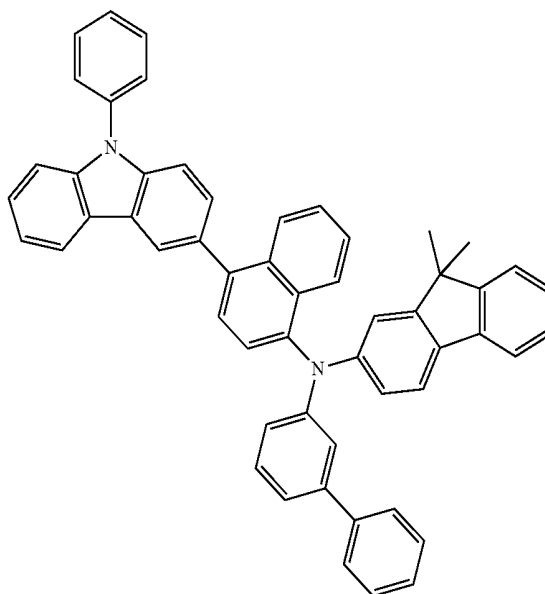


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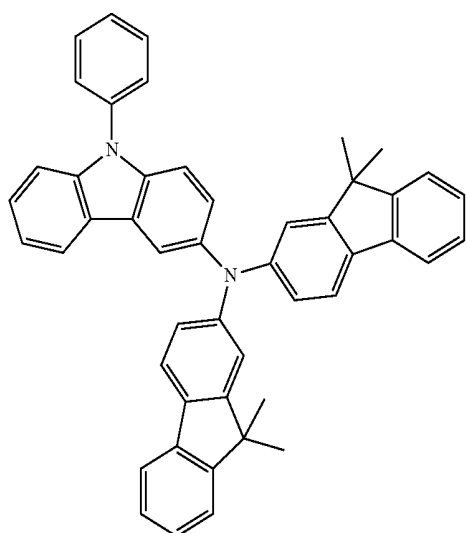
HT9



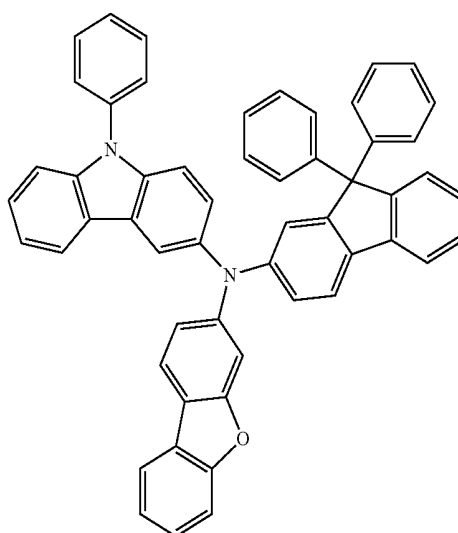
HT10



HT11



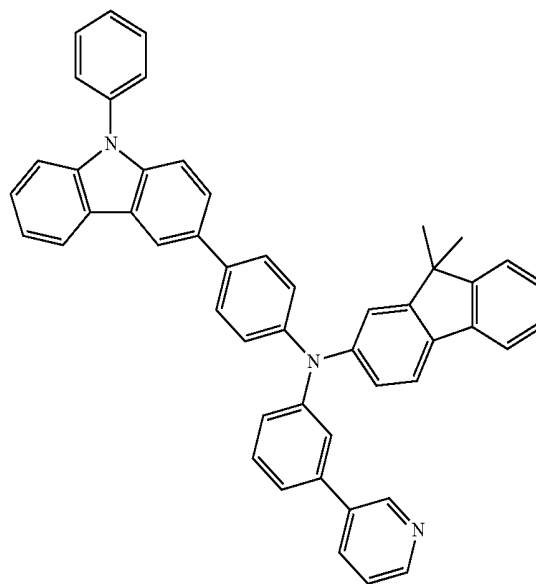
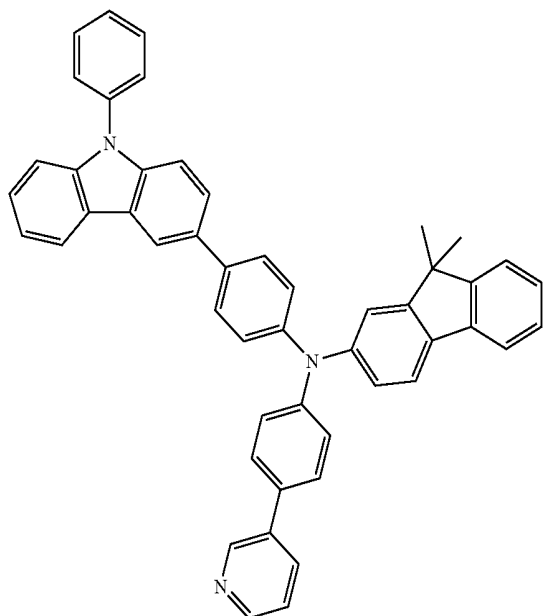
HT12



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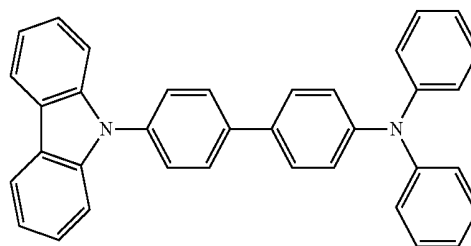
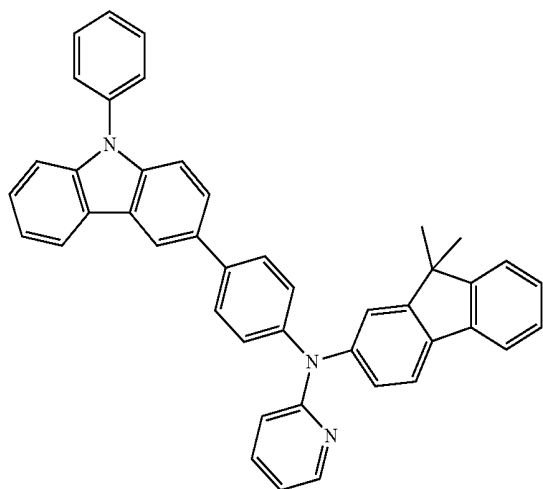
HT13

HT14



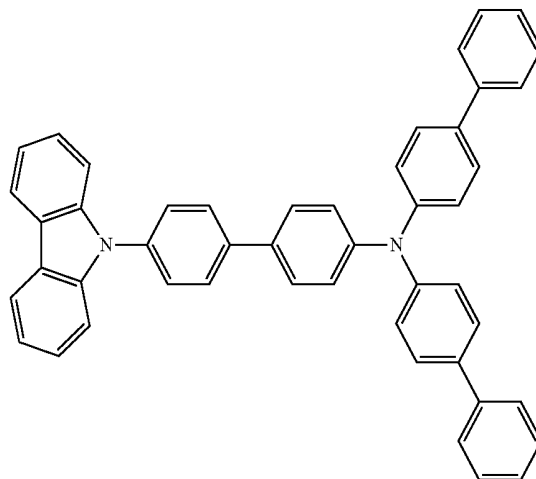
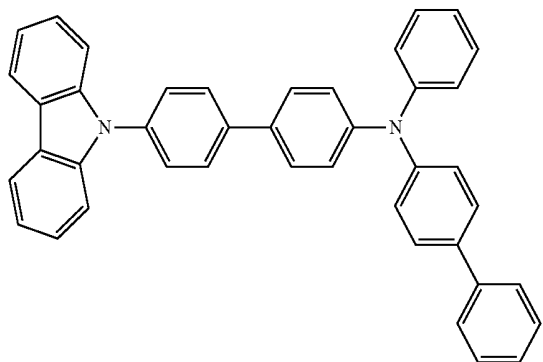
HT15

HT16



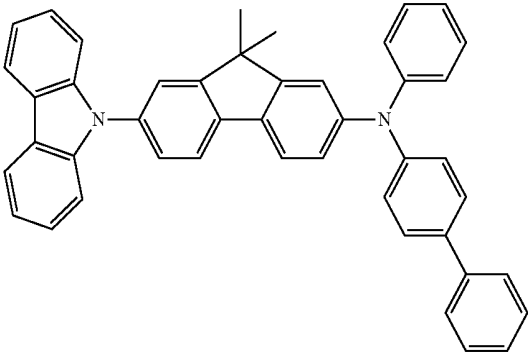
HT17

HT18

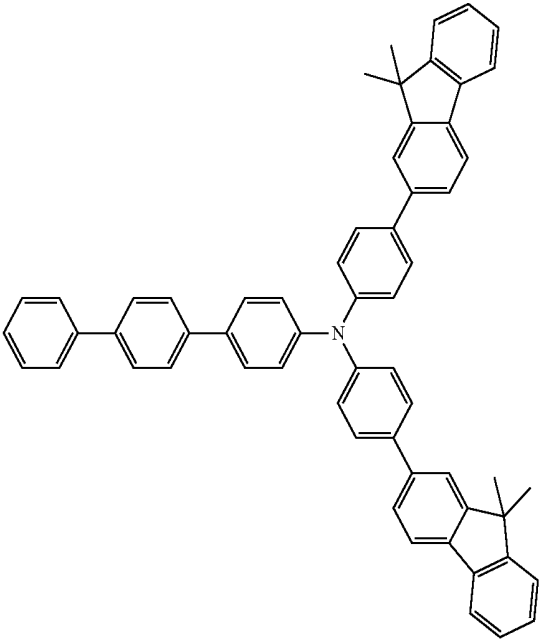


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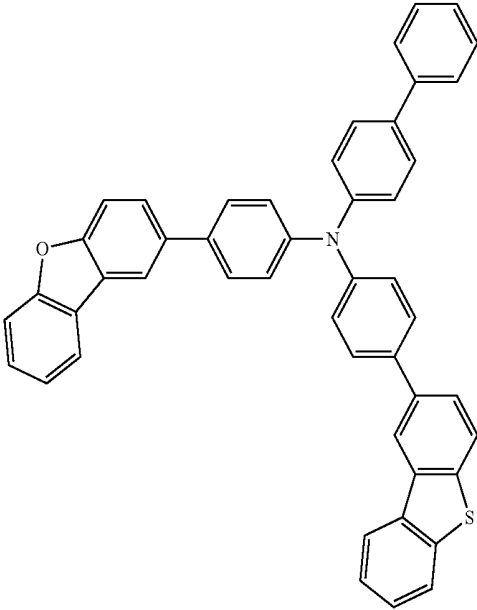
HT19



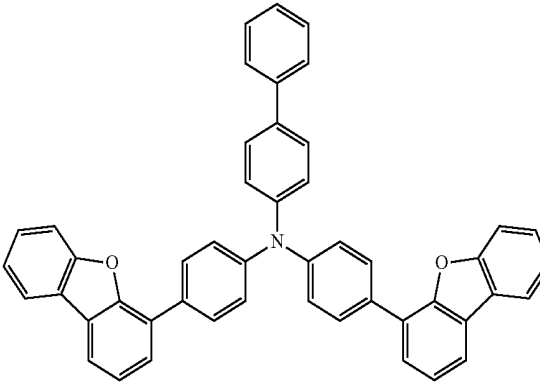
HT20



HT21

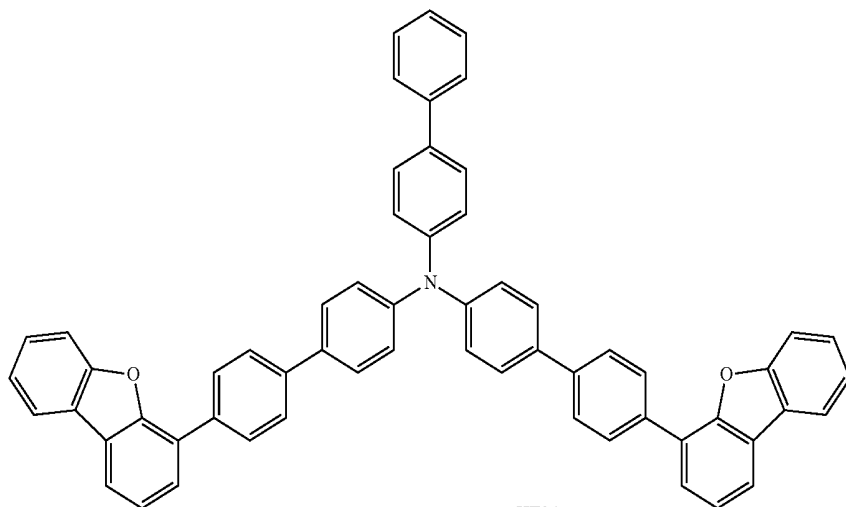


HT22



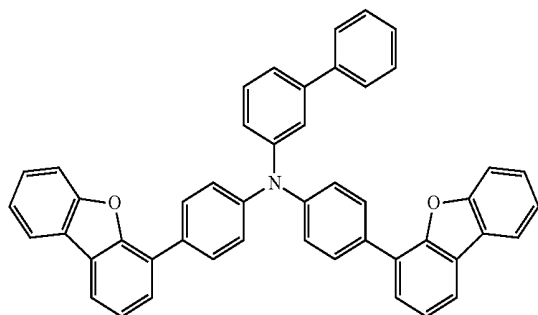
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HT23

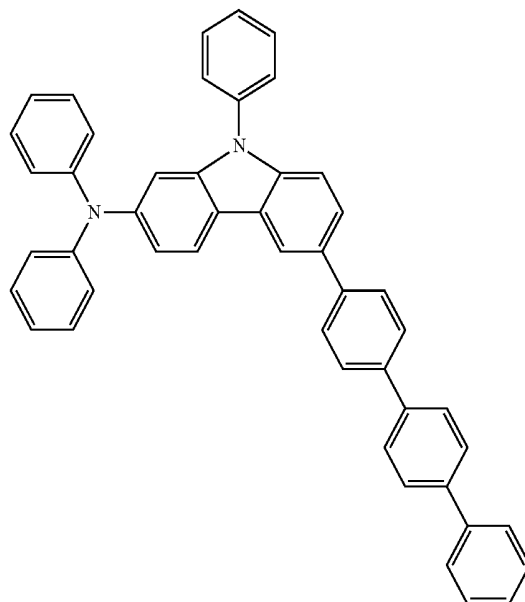


HT24

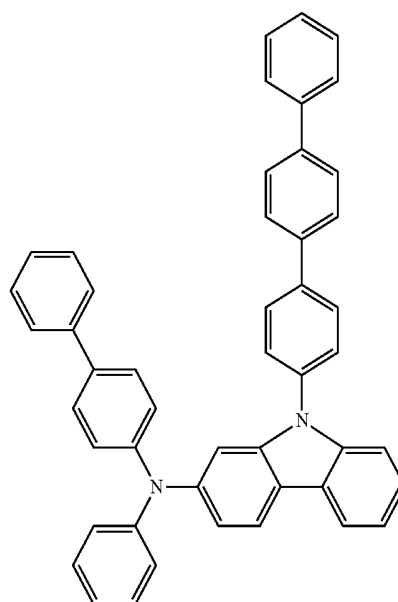
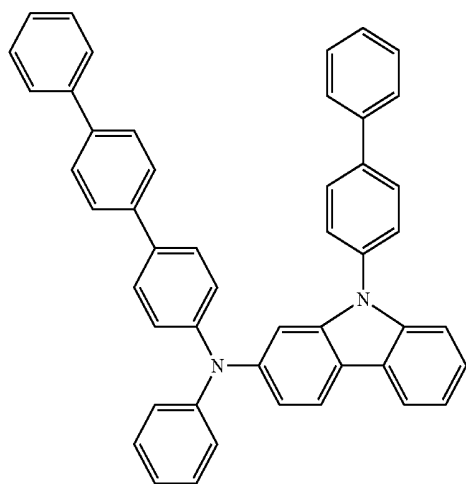
HT25



HT26

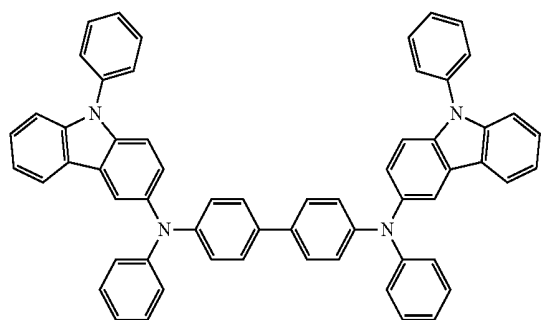


HT27

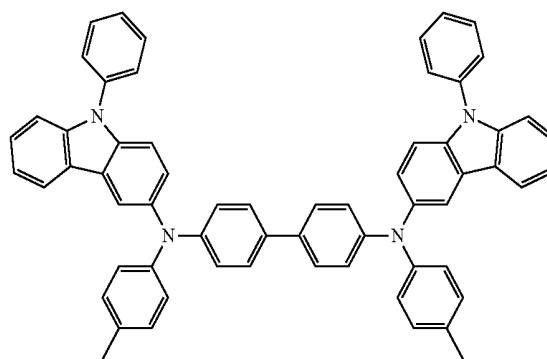


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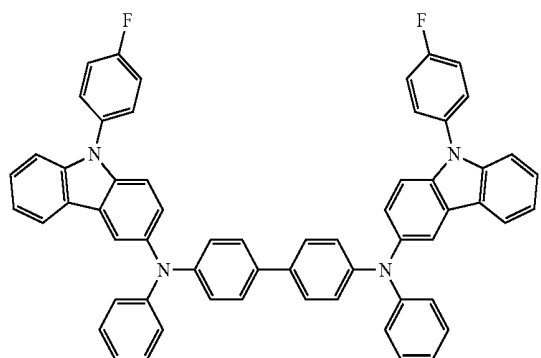
HT28



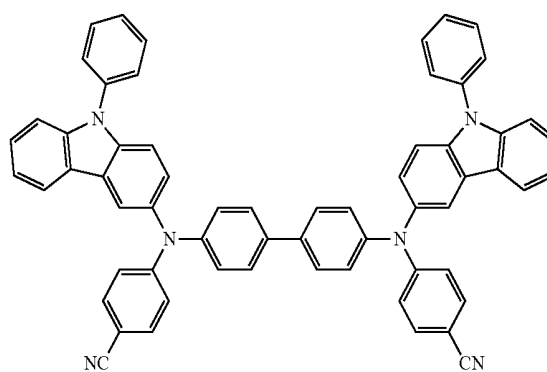
HT29



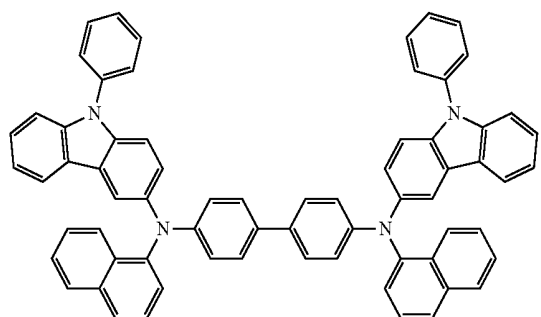
HT30



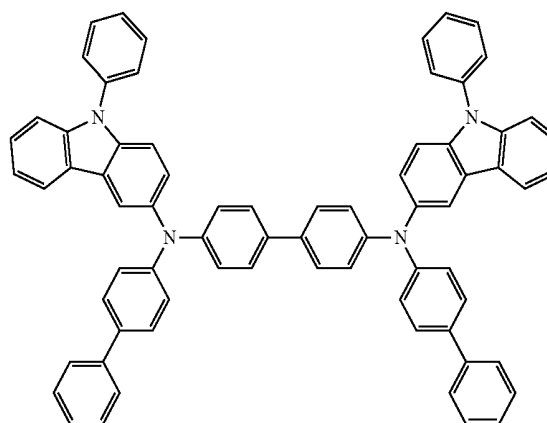
HT31



HT32

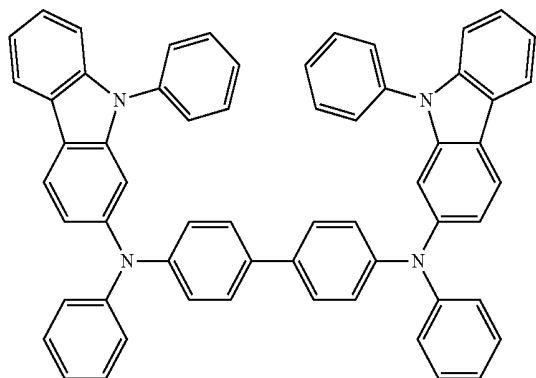


HT33

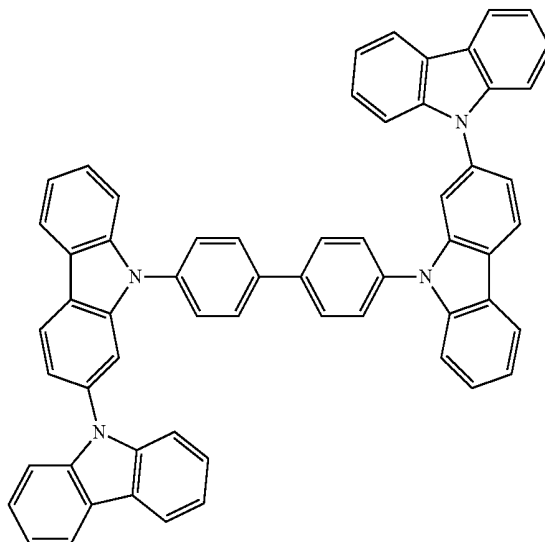


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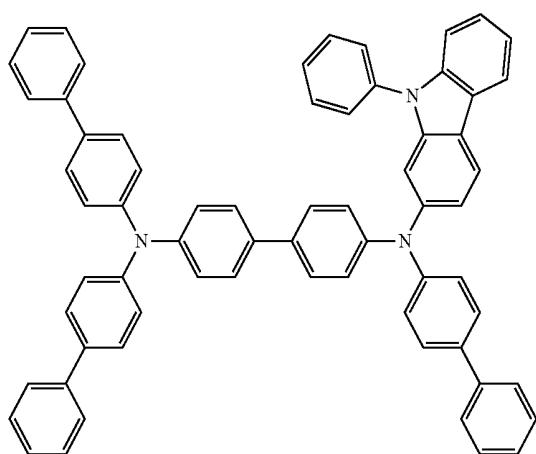
HT34



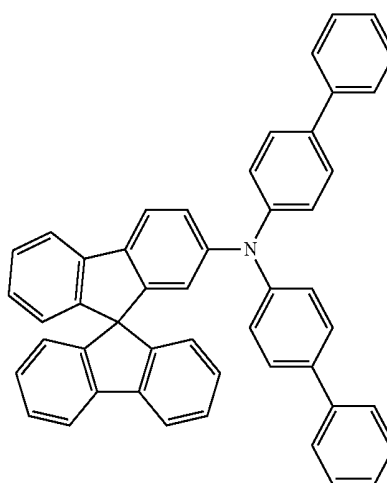
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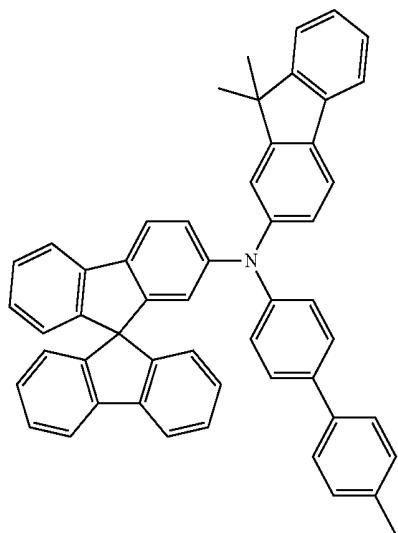
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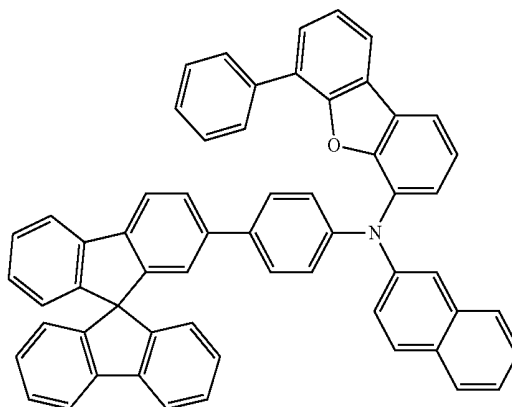
HT37



HT38



HT39



[0151] The thickness of the hole transport region may be in a range of about 100 Å to about 10,000 Å, for example, about 100 Å to about 1,000 Å. When the hole transport region includes at least one selected from a hole injection layer and a hole transport layer, the thickness of the hole injection layer may be in a range of about 100 Å to about 9,000 Å, and in some embodiments, about 100 Å to about 1,000 Å, and the thickness of the hole transport layer may be in a range of about 50 Å to about 2,000 Å, and in some embodiments, about 100 Å to about 1500 Å. When the thicknesses of the hole transport region, the hole injection layer, and the hole transport layer are within any of these ranges, satisfactory hole transporting characteristics may be obtained without a substantial increase in driving voltage.

[0152] The emission auxiliary layer may increase the light-emission efficiency by compensating for an optical resonance distance depending on the wavelength of light emitted by an emission layer, and the electron blocking layer may block or reduce the flow of electrons from an electron transport region. The emission auxiliary layer and the electron blocking layer may include the materials as described above.

[0153] 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.

[0154] The charge-generation material may be, for example, a p-dopant.

[0155] In one embodiment, the p-dopant may have a lowest unoccupied molecular orbital (LUMO) level of about -3.5 eV or less.

[0156] The p-dopant may include at least one selected from a quinone derivative, a metal oxide, and a cyano group-containing compound.

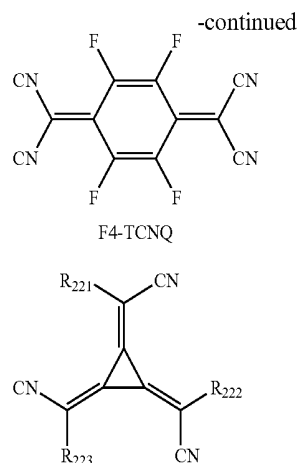
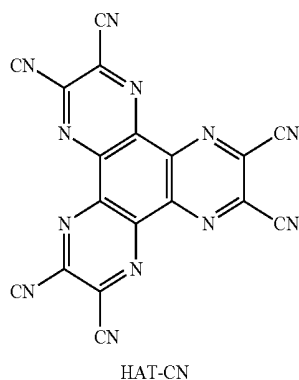
[0157] In some embodiments, the p-dopant may include at least one selected from

[0158] a quinone derivative, such as tetracyanoquinodimethane (TCNQ) and 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F4-TCNQ);

[0159] a metal oxide, such as tungsten oxide or molybdenum oxide;

[0160] 1,4,5,8,9,11-hexaazatriphenylene-hexacarbonitrile (HAT-CN); and

[0161] a compound represented by Formula 221.



[0162] wherein, in Formula 221,

[0163]  $R_{221}$  to  $R_{223}$  may each independently be selected from a substituted or unsubstituted  $C_3$ - $C_{10}$  cycloalkyl group, a substituted or unsubstituted  $C_1$ - $C_{10}$  heterocycloalkyl group, a substituted or unsubstituted  $C_3$ - $C_{10}$  cycloalkenyl group, a substituted or unsubstituted  $C_1$ - $C_{10}$  heterocycloalkenyl group, a substituted or unsubstituted  $C_6$ - $C_{60}$  aryl group, a substituted or unsubstituted  $C_1$ - $C_{60}$  heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, provided that at least one selected from  $R_{221}$  to  $R_{223}$  may include at least one substituent selected from a cyano group, -F, -Cl, -Br, -I, a  $C_1$ - $C_{20}$  alkyl group substituted with -F, a  $C_1$ - $C_{20}$  alkyl group substituted with -Cl, a  $C_1$ - $C_{20}$  alkyl group substituted with -Br, and a  $C_1$ - $C_{20}$  alkyl group substituted with -I.

[0164] 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 an implementation, 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, wherein the two or more layers contact each other or are separated from each other. In an implementation, the emission layer may include two or more materials selected from a red-light emission material, a green-light emission material, and a blue-light emission material, wherein the two or more materials are mixed together in a single layer to emit white light.

[0165] The emission layer may include a host and a dopant. The dopant may include at least one selected from the condensed-cyclic compound represented by Formula 1, a phosphorescent dopant, and a fluorescent dopant.

[0166] In an implementation, the amount of the dopant in the emission layer may be in a range of, e.g., about 0.01 parts to about 15 parts by weight, based on 100 parts by weight of the host, but embodiments are not limited thereto.

[0167] In an implementation, the thickness of the emission layer may be in a range of about 100 Å to about 1,000 Å, e.g., about 200 Å to about 600 Å. When the thickness of the emission layer is within any of these ranges, excellent light-emission characteristics may be obtained without a substantial increase in driving voltage.

[0168] In an implementation, the host may include a compound represented by Formula 301:



[0169] wherein, in Formula 301,

[0170]  $\text{Ar}_{301}$  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,

[0171]  $\text{xb}11$  may be 1, 2, or 3,

[0172]  $\text{L}_{301}$  may be selected from a substituted or unsubstituted  $\text{C}_3$ - $\text{C}_{10}$  cycloalkylene group, a substituted or unsubstituted  $\text{C}_1$ - $\text{C}_{10}$  heterocycloalkylene group, a substituted or unsubstituted  $\text{C}_3$ - $\text{C}_{10}$  cycloalkenylene group, a substituted or unsubstituted  $\text{C}_1$ - $\text{C}_{10}$  heterocycloalkenylene group, a substituted or unsubstituted  $\text{C}_6$ - $\text{C}_{60}$  arylene group, a substituted or unsubstituted  $\text{C}_1$ - $\text{C}_{60}$  heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0173]  $\text{xb}1$  may be an integer of 0 to 5,

[0174]  $\text{R}_{301}$  may be 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 substituted or unsubstituted  $\text{C}_1$ - $\text{C}_{60}$  alkyl group, a substituted or unsubstituted  $\text{C}_2$ - $\text{C}_{60}$  alkenyl group, a substituted or unsubstituted  $\text{C}_2$ - $\text{C}_{60}$  alkynyl group, a substituted or unsubstituted  $\text{C}_1$ - $\text{C}_{60}$  alkoxy group, a substituted or unsubstituted  $\text{C}_3$ - $\text{C}_{10}$  cycloalkyl group, a substituted or unsubstituted  $\text{C}_1$ - $\text{C}_{10}$  heterocycloalkyl group, a substituted or unsubstituted  $\text{C}_3$ - $\text{C}_{10}$  cycloalkenyl group, a substituted or unsubstituted  $\text{C}_1$ - $\text{C}_{10}$  heterocycloalkenyl group, a substituted or unsubstituted  $\text{C}_6$ - $\text{C}_{60}$  aryl group, a substituted or unsubstituted  $\text{C}_6$ - $\text{C}_{60}$  aryloxy group, a substituted or unsubstituted  $\text{C}_6$ - $\text{C}_{60}$  arylthio group, a substituted or unsubstituted  $\text{C}_1$ - $\text{C}_{60}$  heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group,  $-\text{Si}(\text{Q}_{301})(\text{Q}_{302})(\text{Q}_{303})$ ,  $-\text{N}(\text{Q}_{301})(\text{Q}_{302})$ ,  $-\text{B}(\text{Q}_{301})(\text{Q}_{302})$ ,  $-\text{C}(=\text{O})(\text{Q}_{301})$ ,  $-\text{S}(=\text{O})_2(\text{Q}_{301})$ , and  $-\text{P}(=\text{O})(\text{Q}_{301})(\text{Q}_{302})$ , and

[0175]  $\text{xb}21$  may be an integer of 1 to 5,

[0176] wherein  $\text{Q}_{301}$  to  $\text{Q}_{303}$  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.

[0177] In some embodiments,  $\text{Ar}_{301}$  in Formula 301 may be selected from

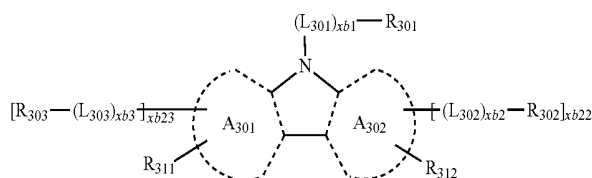
[0178] a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, and a dibenzothiophene group; and

[0179] a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, and a dibenzothiophene group, each substituted with at least one selected from deuterium,  $-\text{F}$ ,  $-\text{Cl}$ ,  $-\text{Br}$ ,  $-\text{I}$ , 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 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  $-\text{P}(=\text{O})(\text{Q}_{31})(\text{Q}_{32})$ ,

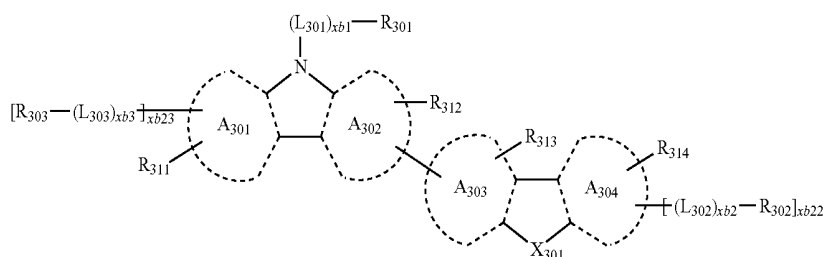
[0180] wherein  $\text{Q}_{31}$  to  $\text{Q}_{33}$  may each independently be selected from a  $\text{C}_1$ - $\text{C}_{10}$  alkyl group, a  $\text{C}_1$ - $\text{C}_{10}$  alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0181] When  $\text{xb}11$  in Formula 301 is 2 or greater, a plurality of  $\text{Ar}_{301}(\text{s})$  may be bound via a single bond.

[0182] 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

[0183] wherein, in Formulae 301-1 to 301-2,

[0184]  $A_{301}$  to  $A_{304}$  may each independently be selected from a benzene group, a naphthalene group, a phenanthrene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a pyridine group, a pyrimidine group, an indene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, an indole group, a carbazole group, a benzocarbazole group, a dibenzocarbazole group, a furan group, a benzofuran group, a dibenzofuran group, a naphthofuran group, a benzonaphthofuran group, a dinaphthofuran group, a thiophene group, a benzothiophene group, a dibenzothiophene group, a naphthothiophene group, a benzonaphthothiophene group, and a dinaphthothiophene group,

[0185]  $X_{301}$  may be O, S, or N- $[(L_{304})_{xb4}-R_{304}]$ ,

[0186]  $R_{311}$  to  $R_{314}$  may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a  $C_1$ - $C_{20}$  alkyl group, a  $C_1$ - $C_{20}$  alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group —Si( $Q_{31}$ )( $Q_{32}$ )( $Q_{33}$ ), —N( $Q_{31}$ )( $Q_{32}$ ), —B( $Q_{31}$ )( $Q_{32}$ ), —C(=O)( $Q_{31}$ ), —S(=O)<sub>2</sub>( $Q_{31}$ ), and —P(=O)( $Q_{31}$ )( $Q_{32}$ ),

[0187]  $xb22$  and  $xb23$  may each independently be 0, 1, or 2,

[0188] descriptions of  $L_{301}$ ,  $xb1$ ,  $R_{301}$ , and  $Q_{31}$  to  $Q_{33}$  may each independently be the same as descriptions thereof provided herein,

[0189] descriptions of  $L_{302}$  to  $L_{304}$  may each independently be the same as the description provided herein in connection with  $L_{301}$ ,

[0190] descriptions of  $xb2$  to  $xb4$  may each independently be the same as the description provided herein in connection with  $xb1$ , and

[0191] descriptions of  $R_{302}$  to  $R_{304}$  may each independently be the same as the description provided herein in connection with  $R_{301}$ .

[0192] In some embodiments, in Formulae 301, 301-1, and 301-2,  $L_{301}$  to  $L_{304}$  may each independently be selected from

[0193] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylylene group, a fluoranthenylylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylylene group, a hexacenylylene group, a pentacenylylene group, a thiophenylylene group, a furanylylene group, a carbazolylylene group, an indolylylene group, an isoindolylylene group, a benzofuranylylene group, a benzothiophenylylene group, a benzofuranylylene group, a dibenzothiophenylylene group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, a pyridinylylene group, an imidazolylylene group, a pyrazolylylene group, a thiazolylylene group, an isothiazolylylene group, an oxazolylylene group, an isoxazolylylene group, a thiadiazolylylene group, an oxadiazolylylene group, a pyrazinylylene group, a pyrimidinylylene group, a pyridazinylylene group, a triazinylylene group, a quinolinylylene group, an isoquinolinylylene group, a benzoquinolinylylene group, a phthalazinylylene group, a naphthyridinylylene group, a quinoxalinylylene group, a quinazolinylylene group, a cinnolinylylene group, a phenanthridinylylene group, an acridinylylene group, a phenanthrolinylylene group, a phenazinylylene group, a benzimidazolylylene group, an isobenzothiazolylylene group,

a benzoxazolylylene group, an isobenzoxazolylylene group, a triazolylylene group, a tetrazolylylene group, an imidazopyridinylylene group, an imidazopyrimidininylylene group, and an azacarbazolylylene group; and

[0194] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylylene group, a benzofluorenylylene group, a dibenzofluorenylylene group, a phenanthrenylene group, an anthracenylylene group, a fluoranthenylylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylylene group, a hexacenylylene group, a pentacenylylene group, a thiophenylylene group, a furanylylene group, a carbazolylylene group, an indolylylene group, an isoindolylylene group, a benzofuranylylene group, a benzothiophenylylene group, a benzofuranylylene group, a dibenzothiophenylylene group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, a pyridinylylene group, an imidazolylylene group, a pyrazolylylene group, a thiazolylylene group, an isothiazolylylene group, an oxazolylylene group, an isoxazolylylene group, a thiadiazolylylene group, an oxadiazolylylene group, a pyrazinylylene group, a pyrimidinylylene group, a pyridazinylylene group, a triazinylylene group, a quinolinylylene group, an isoquinolinylylene group, a benzoquinolinylylene group, a phthalazinylylene group, a naphthyridinylylene group, a quinoxalinylylene group, a quinazolinylylene group, a cinnolinylylene group, a phenanthridinylylene group, an acridinylylene group, a phenanthrolinylylene group, a phenazinylylene group, a benzimidazolylylene group, an isobenzothiazolylylene group, a benzoxazolylylene group, an isobenzoxazolylylene group, a triazolylylene group, a tetrazolylylene group, an imidazopyridinylylene group, an imidazopyrimidininylylene group, and an azacarbazolylylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a  $C_1$ - $C_{20}$  alkyl group, a  $C_1$ - $C_{20}$  alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolynyl group, an isoquinolynyl group, a benzoquinolynyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalynyl group, a quinazolynyl group, a cinnolynyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an azacarbazolyl group, —Si( $Q_{31}$ )( $Q_{32}$ )( $Q_{33}$ ), —N( $Q_{31}$ )( $Q_{32}$ ), —B( $Q_{31}$ )( $Q_{32}$ ), —C(=O)( $Q_{31}$ ), —S(=O)<sub>2</sub>( $Q_{31}$ ), and —P(=O)( $Q_{31}$ )( $Q_{32}$ ).

**[0195]** wherein descriptions of  $Q_{31}$  to  $Q_{33}$  may each independently be the same as descriptions thereof provided herein.

**[0196]** In some embodiments, in Formulae 301, 301-1, and 301-2,  $R_{301}$  to  $R_{304}$  may each independently be selected from

**[0197]** 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 hexacacenyl group, a pentacacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group; and

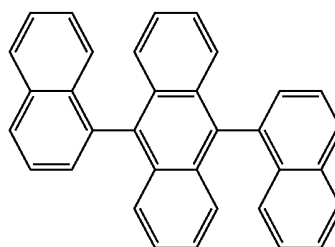
**[0198]** a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacacenyl group, a pentacacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, each substituted with at least one selected from deuterium,  $-F$ ,  $-Cl$ ,  $-Br$ ,  $-I$ , a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a  $C_1$ - $C_{20}$  alkyl group, a  $C_1$ - $C_{20}$  alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl

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

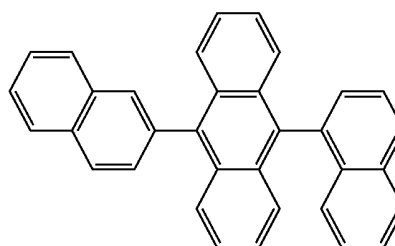
**[0199]** wherein descriptions of  $Q_{31}$  to  $Q_{33}$  may each independently be the same as descriptions thereof provided herein.

**[0200]** In one or more embodiments, the host may include an alkaline earth-metal complex. For example, the host may be selected from a beryllium (Be) complex (e.g., Compound H55), a magnesium (Mg) complex, and a zinc (Zn) complex.

**[0201]** The host may include at least one selected from 9,10-di-(2-naphthyl)anthracene (ADN), 2-methyl-9,10-bis(naphthalen-2-yl)anthracene (MADN), 9,10-di-(2-naphthyl)-2-t-butyl-anthracene (TBADN), 4,4'-bis(N-carbazolyl)-1,1'-biphenyl (CBP), 1,3-di-9-carbazolylbenzene (mCP), 1,3,5-tri(carbazol-9-yl)benzene (TCP), and Compounds H1 to H55.

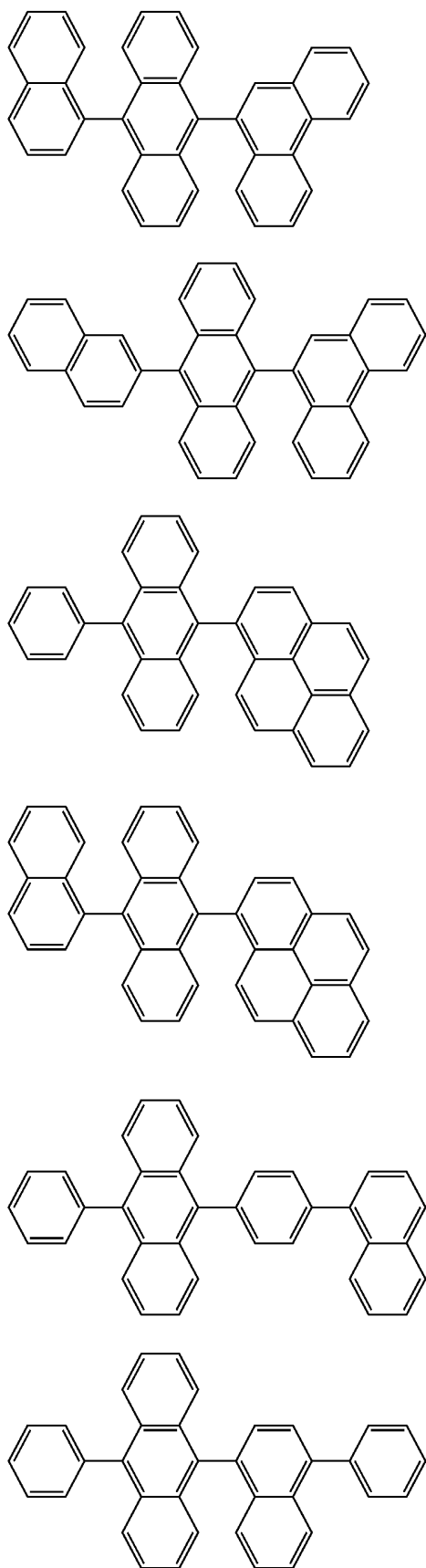


H1

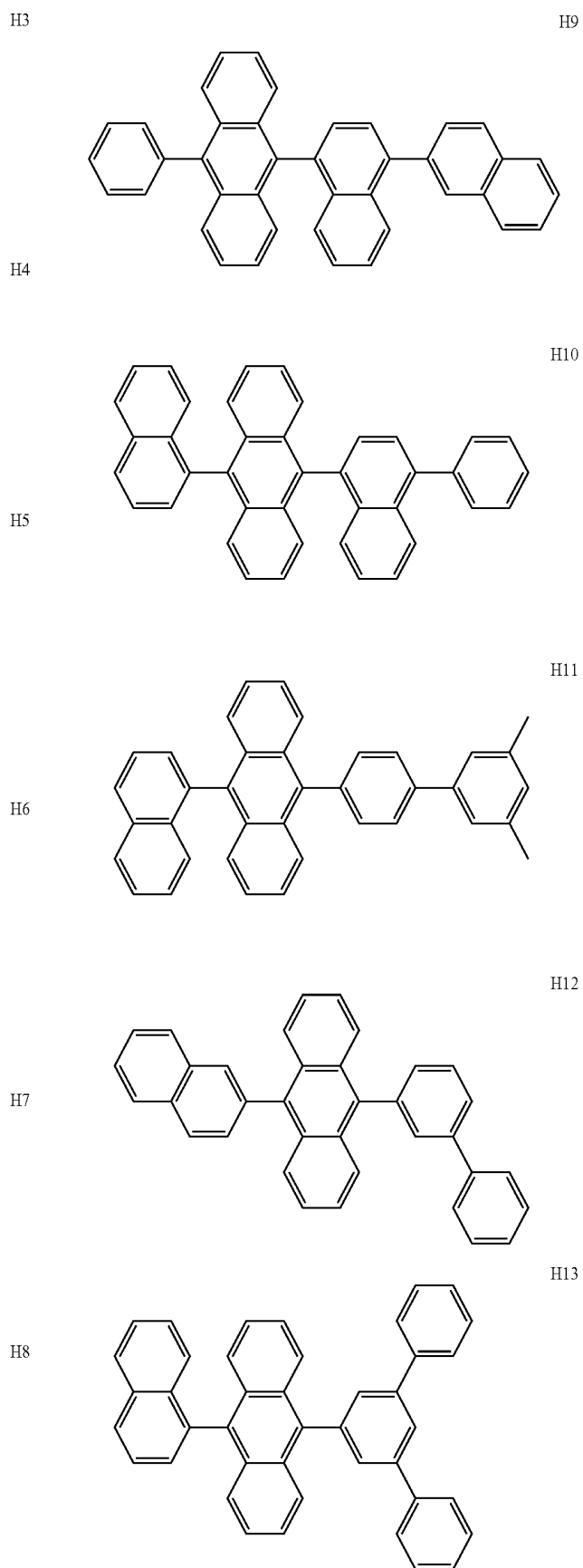


H2

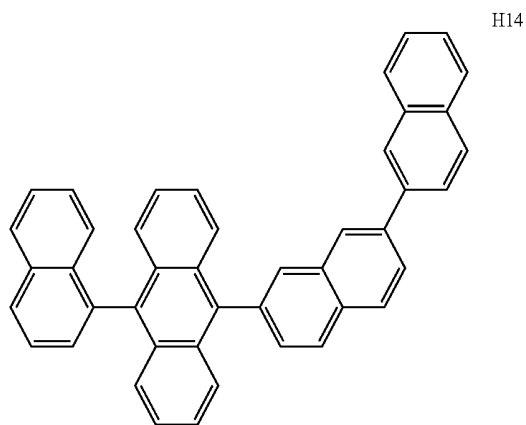
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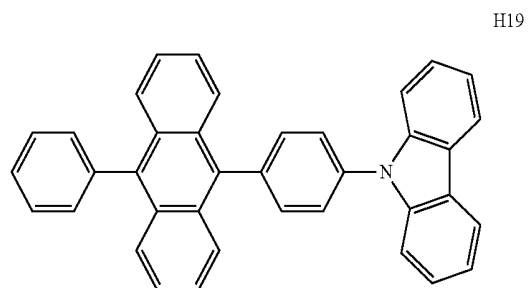
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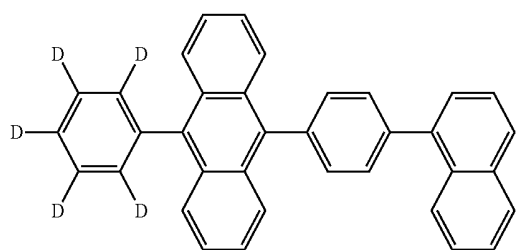
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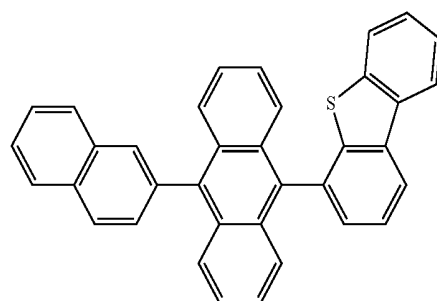
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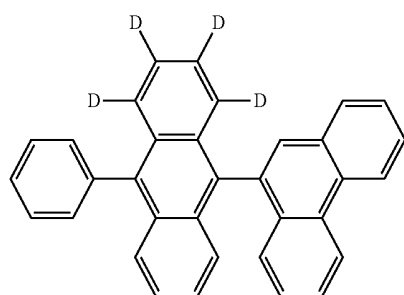
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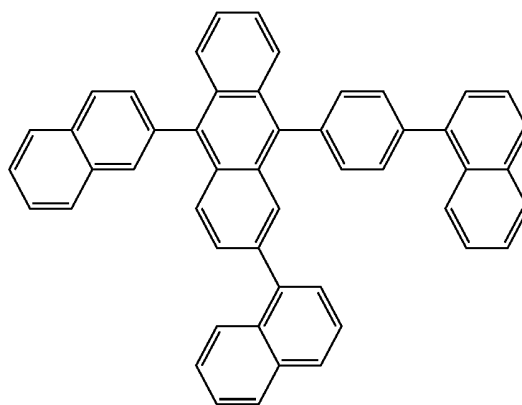
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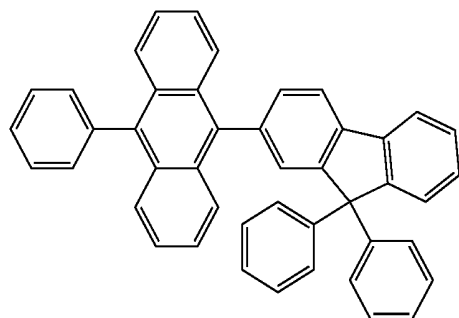
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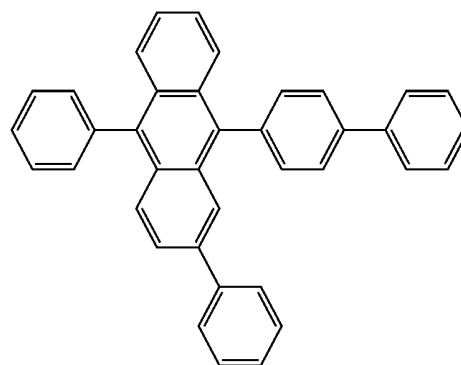
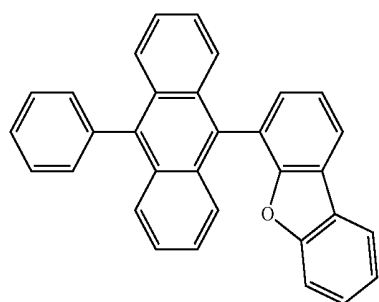
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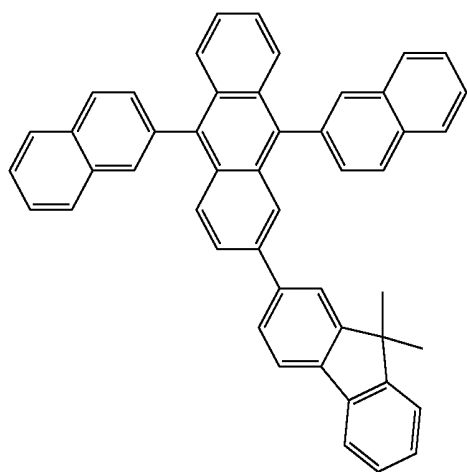
H17



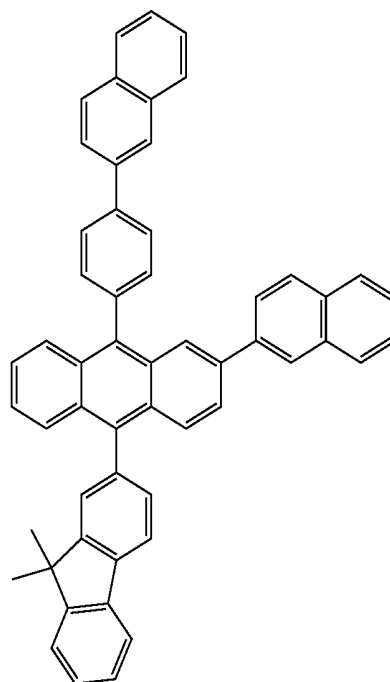
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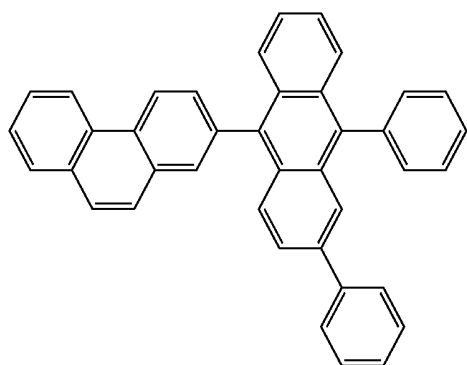
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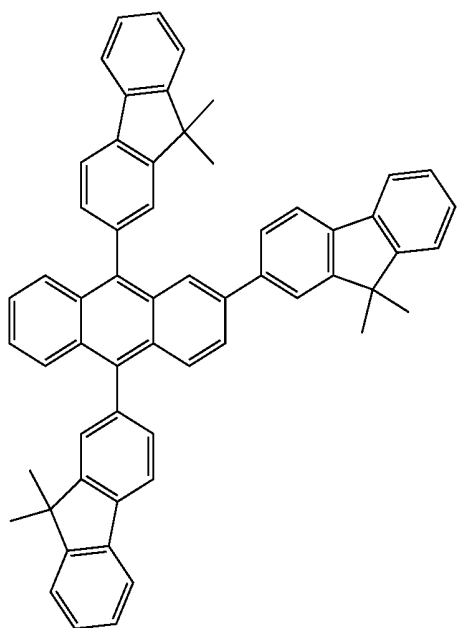
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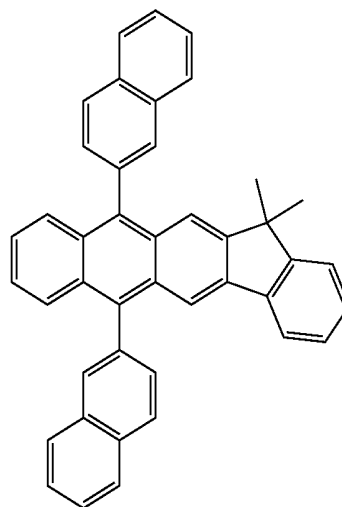
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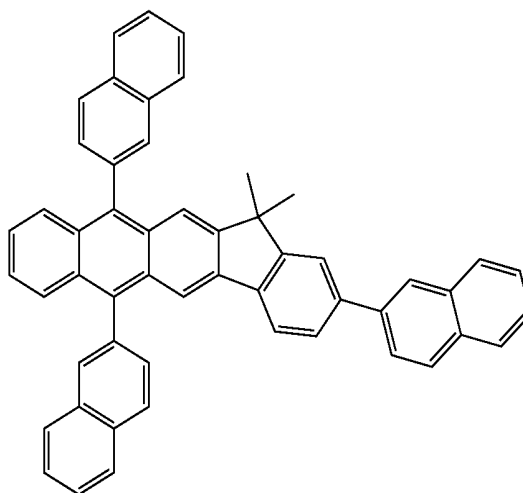
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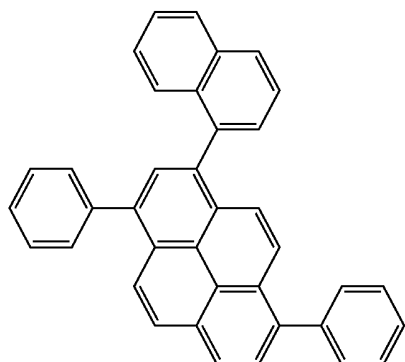
H23



H28

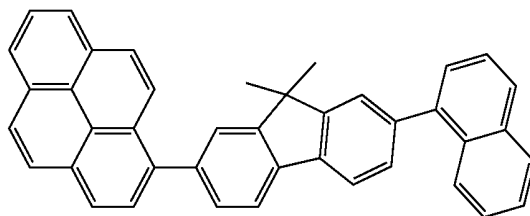


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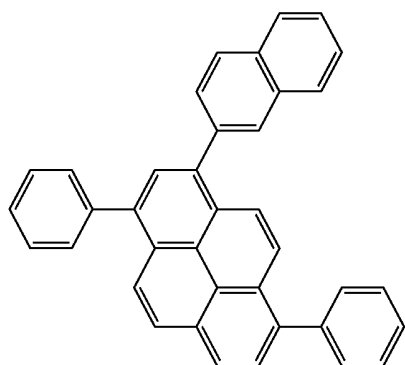


H29

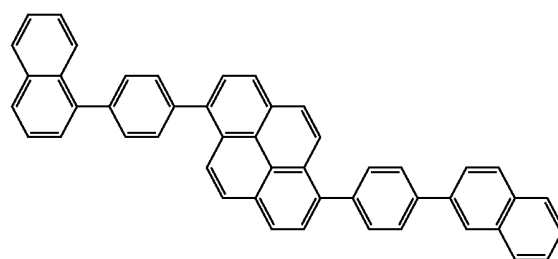
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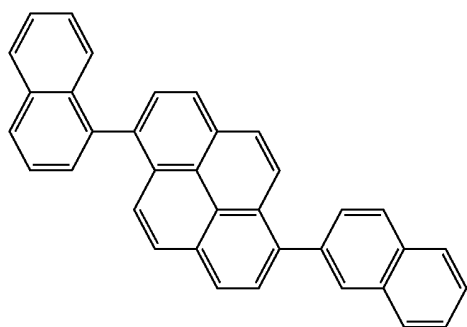
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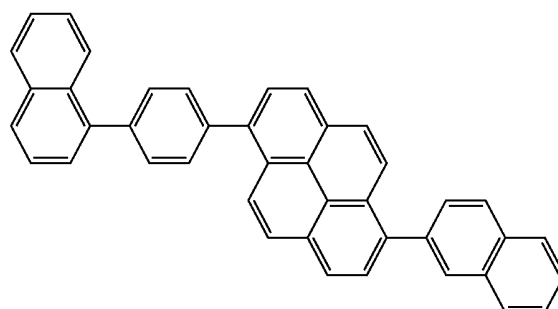
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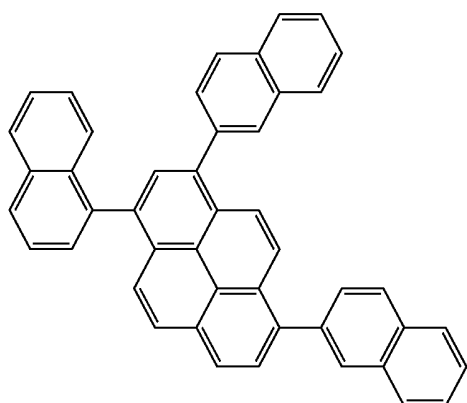
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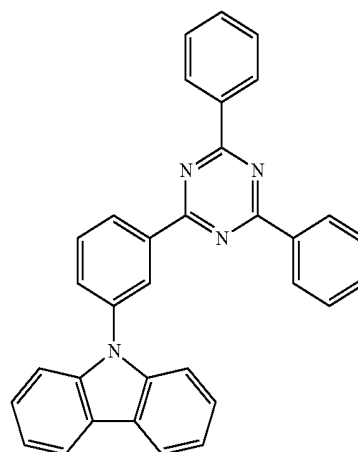
H31



H35

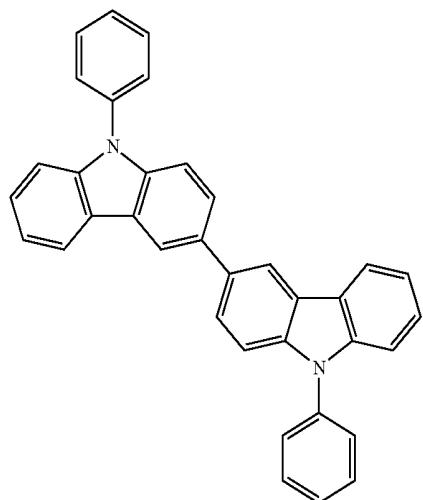
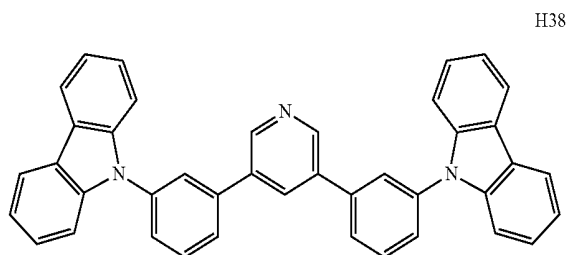
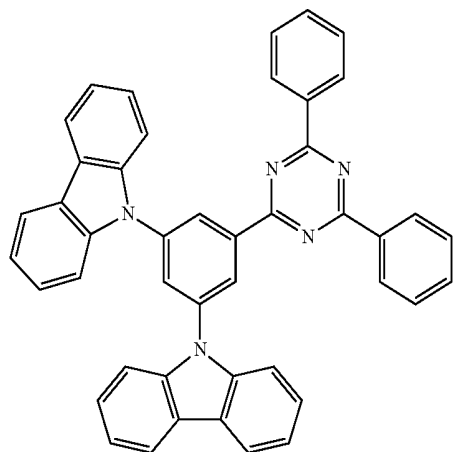


H32

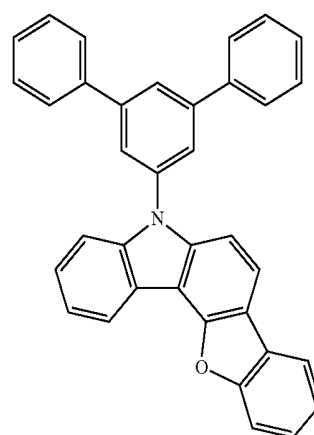
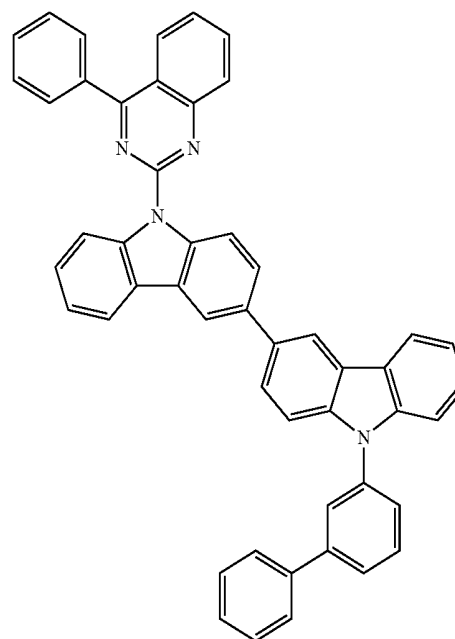
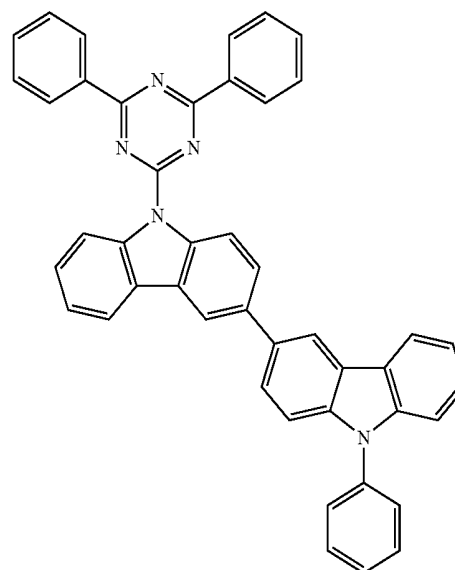


H36

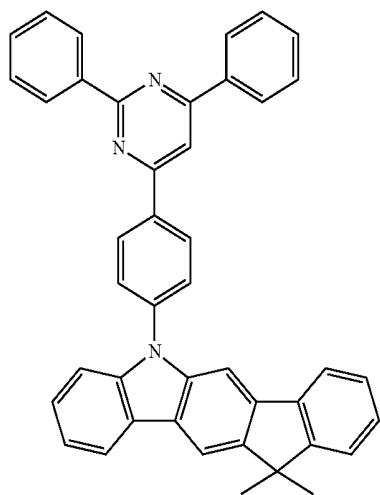
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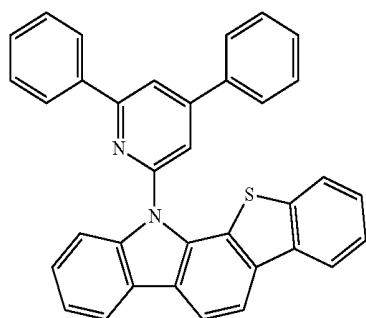
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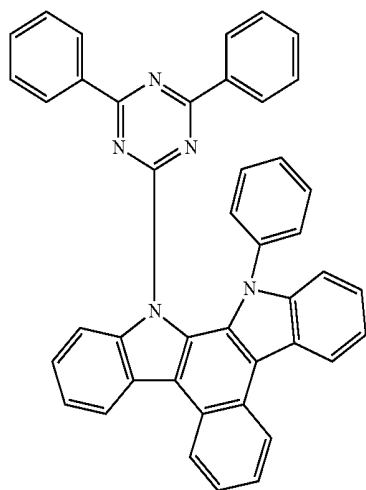
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H43

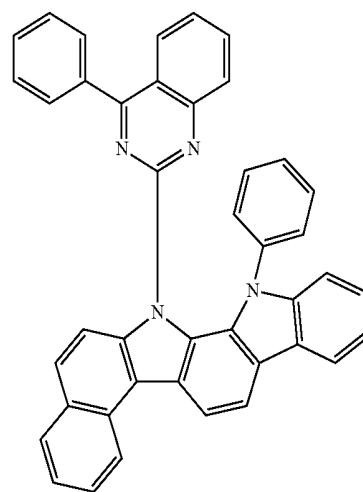


H44

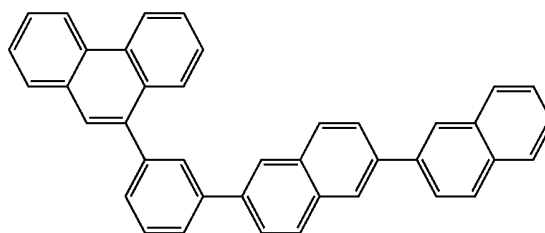


H45

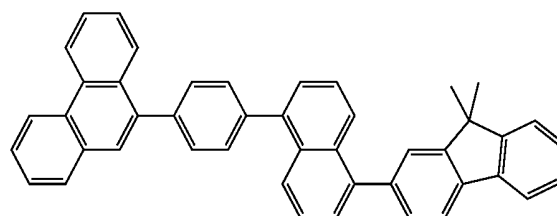
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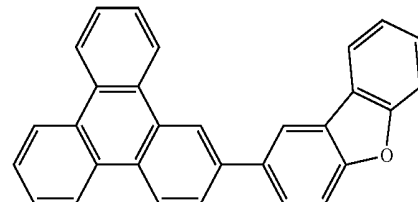
H46



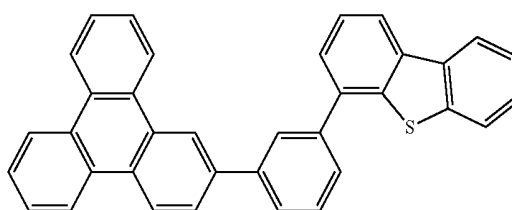
H47



H48

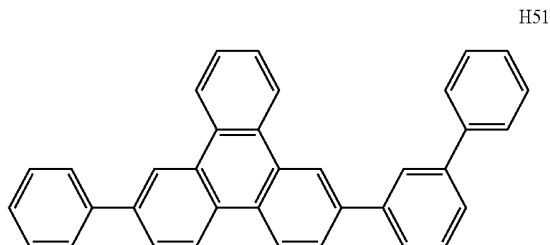


H49

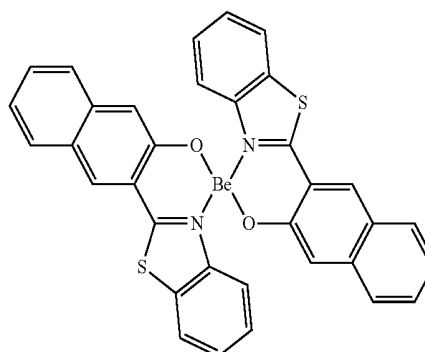


H50

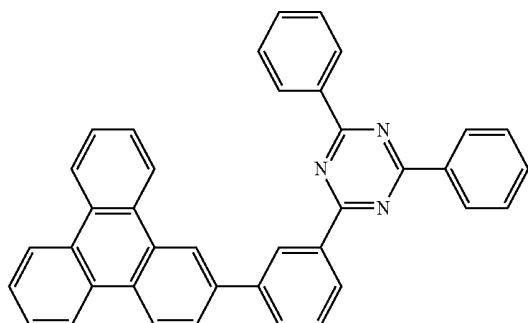
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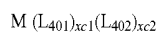


H52



[0202] In an implementation, the dopant may further include, in addition to the condensed-cyclic compound represented by Formula 1, a phosphorescent dopant or a fluorescent dopant.

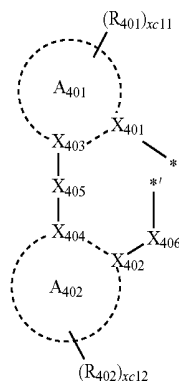
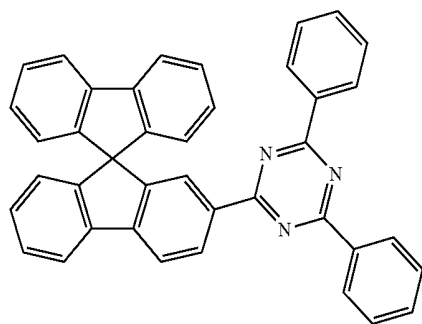
[0203] The phosphorescent dopant may include an organometallic complex represented by Formula 401:



Formula 401

Formula 402

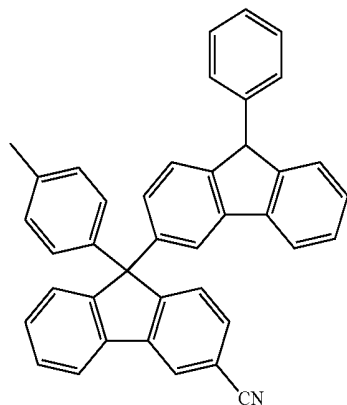
H53



[0204] wherein, in Formulae 401 and 402,

[0205] 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),

H54



[0206]  $L_{401}$  may be selected from ligands represented by Formula 402, and  $xc1$  may be an integer of 1, 2, and 3; when  $xc1$  is 2 or greater, a plurality of  $L_{401}(S)$  may be identical to or different from each other,

[0207]  $L_{402}$  may be an organic ligand, and  $xc2$  may be an integer of 0 to 4; when  $xc2$  is 2 or greater, a plurality of  $L_{402}(s)$  may be identical to or different from each other,

[0208]  $X_{401}$  to  $X_{404}$  may each independently be nitrogen or carbon,

[0209]  $X_{401}$  and  $X_{403}$  may be bound via a single bond or a double bond,  $X_{402}$  and  $X_{404}$  may be bound via a single bond or a double bond,

[0210]  $A_{401}$  and  $A_{402}$  may each independently be a  $C_5$ - $C_{60}$  carbocyclic group or a  $C_1$ - $C_{60}$  heterocyclic group,

[0211]  $X_{405}$  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<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>1</sub>-C<sub>20</sub> alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group,

[0212] X<sub>406</sub> may be a single bond, O, or S,

[0213] R<sub>401</sub> and R<sub>402</sub> 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<sub>1</sub>-C<sub>20</sub> alkyl group, a substituted or unsubstituted C<sub>1</sub>-C<sub>20</sub> alkoxy group, a substituted or unsubstituted C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a substituted or unsubstituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a substituted or unsubstituted C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a substituted or unsubstituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a substituted or unsubstituted C<sub>6</sub>-C<sub>60</sub> aryl group, a substituted or unsubstituted C<sub>6</sub>-C<sub>60</sub> aryloxy group, a substituted or unsubstituted C<sub>6</sub>-C<sub>60</sub> arylthio group, a substituted or unsubstituted C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(Q<sub>401</sub>)(Q<sub>402</sub>)(Q<sub>403</sub>), —N(Q<sub>401</sub>)(Q<sub>402</sub>), —B(Q<sub>401</sub>)(Q<sub>402</sub>), —C(=O)(Q<sub>401</sub>), —S(=O)<sub>2</sub>(Q<sub>401</sub>), and —P(=O)(Q<sub>401</sub>)(Q<sub>402</sub>), wherein Q<sub>401</sub> to Q<sub>403</sub> may each independently be selected from a C<sub>1</sub>-C<sub>10</sub> alkyl group, a C<sub>1</sub>-C<sub>10</sub> alkoxy group, a C<sub>6</sub>-C<sub>20</sub> aryl group, and a C<sub>1</sub>-C<sub>20</sub> heteroaryl group,

[0214] xc11 and xc12 may each independently be an integer of 0 to 10, and

[0215] \* and \*' in Formula 402 may each independently indicate a binding site to M in Formula 401.

[0216] According to an embodiment, A<sub>401</sub> and A<sub>402</sub> in Formula 402 may each independently be selected from a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, an indene group, a pyrrole group, a thiophene group, a furan group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a quinoxaline group, a quinazoline group, a carbazole group, a benzimidazole group, a benzofuran group, a benzothiophene group, an isobenzothiophene group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a dibenzofuran group, and a dibenzothiophene group.

[0217] In one or more embodiments, in Formula 402, i) X<sub>401</sub> may be nitrogen, and X<sub>402</sub> may be carbon, or ii) X<sub>401</sub> and X<sub>402</sub> may both be nitrogen.

[0218] In one or more embodiments, R<sub>402</sub> and R<sub>401</sub> in Formula 402 may each independently be selected from

[0219] 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<sub>1</sub>-C<sub>20</sub> alkyl group, and a C<sub>1</sub>-C<sub>20</sub> alkoxy group;

[0220] a C<sub>1</sub>-C<sub>20</sub> alkyl group and a C<sub>1</sub>-C<sub>20</sub> 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 adamantyl group, a norbornanyl group, and a norbornenyl group;

[0221] a cyclopentyl group, a cyclohexyl group, an adamantyl 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 quinazoliny group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

[0222] a cyclopentyl group, a cyclohexyl group, an adamantyl 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 quinazoliny 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<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>1</sub>-C<sub>20</sub> alkoxy group, a cyclopentyl group, a cyclohexyl group, an adamantyl 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 quinazoliny group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

[0223] —Si(Q<sub>401</sub>)(Q<sub>402</sub>)(Q<sub>403</sub>), —N(Q<sub>401</sub>)(Q<sub>402</sub>), —B(Q<sub>401</sub>)(Q<sub>402</sub>), —C(=O)(Q<sub>401</sub>), —S(=O)<sub>2</sub>(Q<sub>401</sub>), and —P(=O)(Q<sub>401</sub>)(Q<sub>402</sub>),

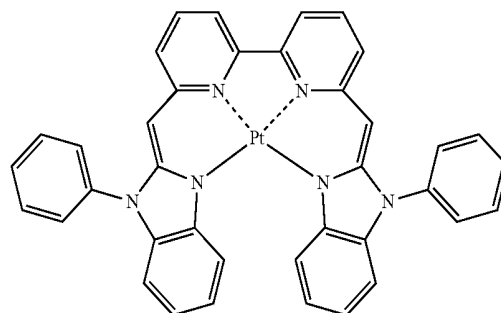
[0224] wherein Q<sub>401</sub> to Q<sub>403</sub> may each independently be selected from a C<sub>1</sub>-C<sub>10</sub> alkyl group, a C<sub>1</sub>-C<sub>10</sub> alkoxy group, a phenyl group, a biphenyl group, and a naphthyl group.

[0225] In one or more embodiments, when xc1 in Formula 401 is 2 or greater, two A<sub>401</sub>(s) of a plurality of L<sub>401</sub>(s) may optionally be bound via X<sub>407</sub> as a linking group; or two A<sub>402</sub>(s) may optionally be bound via X<sub>408</sub> as a linking group (see Compounds PD1 to PD4 and PD7 below). X<sub>407</sub> and X<sub>408</sub> may each independently be a single bond, \*—O—\*, \*—S—\*, \*—C(=O)—\*, \*—N(Q<sub>413</sub>)\*, \*—C(Q<sub>413</sub>)(Q<sub>414</sub>)\*, or \*—C(Q<sub>413</sub>)=C(Q<sub>414</sub>)\*, wherein Q<sub>413</sub> and Q<sub>414</sub> may each independently be hydrogen, deuterium, a C<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>1</sub>-C<sub>20</sub> alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group.

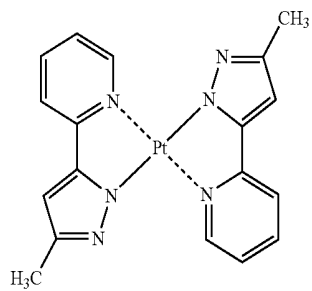
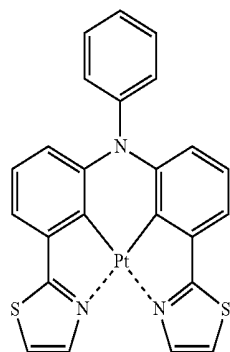
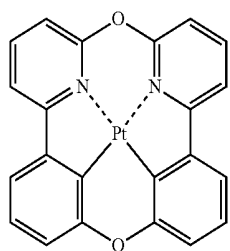
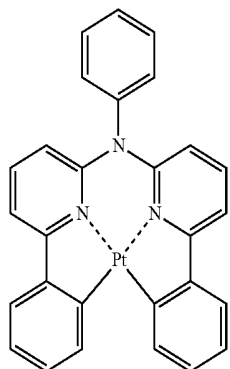
[0226] L<sub>402</sub> in Formula 401 may be a monovalent, divalent, or trivalent organic ligand. For example, L<sub>402</sub> may be selected from halogen, diketone (e.g., acetylacetonate), carboxylic acid (e.g., picolinate), —C(=O), isonitrile, —CN, and phosphorus (e.g., phosphine or phosphite).

[0227] In an implementation, the phosphorescent dopant may be selected from, e.g., Compounds PD1 to PD25.

PD1

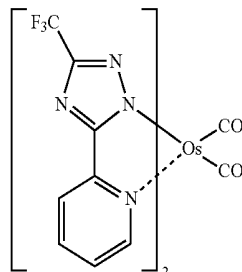


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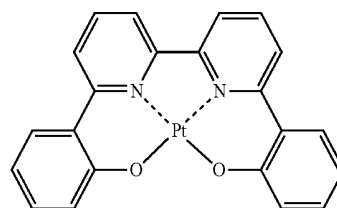
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PD2



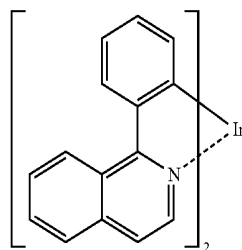
PD6

PD3



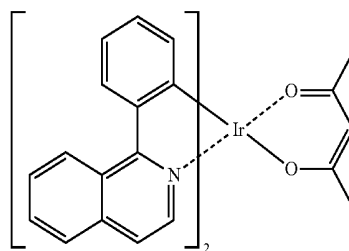
PD7

PD4



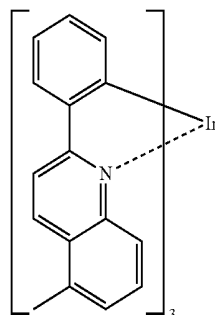
PD8

PD5

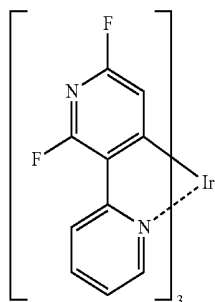
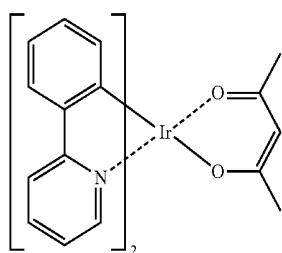
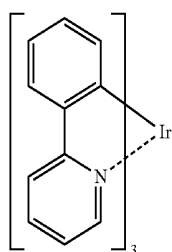
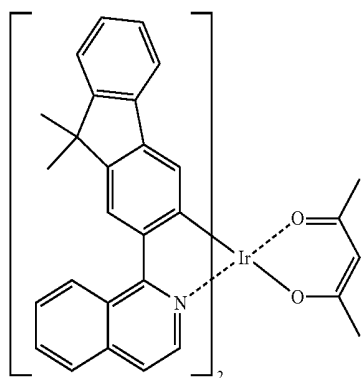
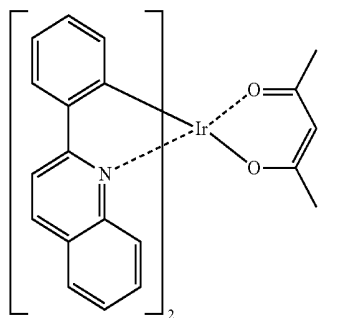


PD9

PD10

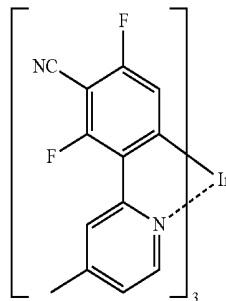


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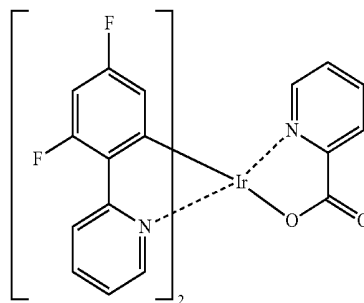
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PD11



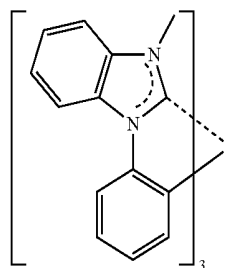
PD16

PD12



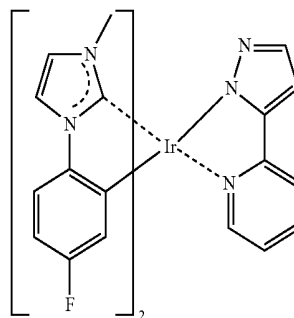
PD17

PD13



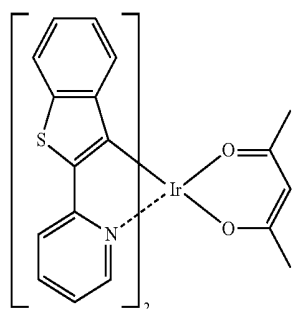
PD18

PD14



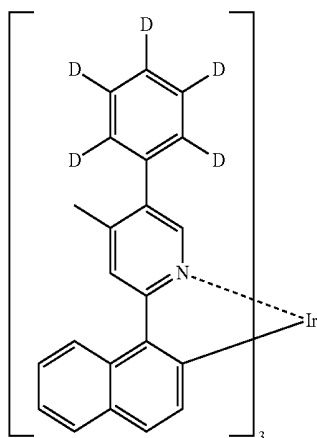
PD19

PD15



PD20

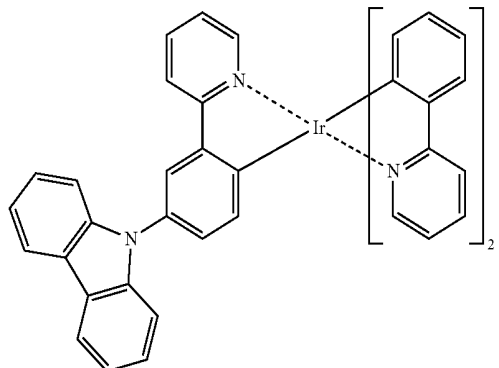
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PD21

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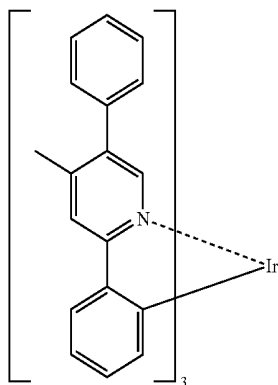
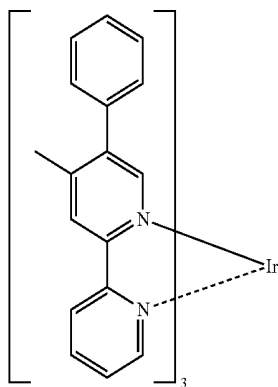
PD25



[0228] The fluorescent dopant may include an arylamine compound or a styrylamine compound.

PD22

[0229] The fluorescent dopant may further include, in addition to the condensed-cyclic compound represented by Formula 1, a compound represented by Formula 501:



PD23

[0230] wherein, in Formula 501,

[0231] Ar<sub>501</sub> may be a substituted or unsubstituted C<sub>5</sub>-C<sub>60</sub> carbocyclic group or a substituted or unsubstituted C<sub>1</sub>-C<sub>60</sub> heterocyclic group,

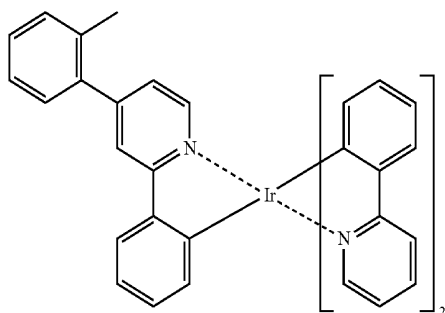
[0232] L<sub>501</sub> to L<sub>503</sub> may each independently be selected from a substituted or unsubstituted C<sub>3</sub>-C<sub>10</sub> cycloalkylene group, a substituted or unsubstituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkylene group, a substituted or unsubstituted C<sub>3</sub>-C<sub>10</sub> cycloalkenylene group, a substituted or unsubstituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkenylene group, a substituted or unsubstituted C<sub>6</sub>-C<sub>60</sub> arylene group, a substituted or unsubstituted C<sub>1</sub>-C<sub>60</sub> heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0233] xd1 to xd3 may each independently be an integer of 0 to 3,

[0234] R<sub>501</sub> and R<sub>502</sub> may each independently be selected from a substituted or unsubstituted C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a substituted or unsubstituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a substituted or unsubstituted C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a substituted or unsubstituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a substituted or unsubstituted C<sub>6</sub>-C<sub>60</sub> aryl group, a substituted or unsubstituted C<sub>6</sub>-C<sub>60</sub> aryloxy group, a substituted or unsubstituted C<sub>6</sub>-C<sub>60</sub> arylthio group, a substituted or unsubstituted C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, and

[0235] xd4 may be an integer of 1 to 6.

PD24



**[0236]** In some embodiments, Ar<sub>501</sub> in Formula 501 may be selected from

**[0237]** 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

**[0238]** a naphthalene group, a heptalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, and an indenophenanthrene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>1</sub>-C<sub>20</sub> alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

**[0239]** In one or more embodiments, L<sub>501</sub> to L<sub>503</sub> in Formula 501 may each independently be selected from

**[0240]** a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylylene group, a fluoranthenylylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylylene group, a hexacenylylene group, a pentacenylylene group, a thiophenylylene group, a furanylylene group, a carbazolylylene group, an indolylylene group, an isoindolylylene group, a benzofuranylylene group, a benzothiophenylylene group, a dibenzofuranylylene group, a dibenzothiophenylylene group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, and a pyridinylylene group; and

**[0241]** a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylylene group, a benzofluorenylylene group, a dibenzofluorenylylene group, a phenanthrenylene group, an anthracenylylene group, a fluoranthenylylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylylene group, a hexacenylylene group, a pentacenylylene group, a thiophenylylene group, a furanylylene group, a carbazolylylene group, an indolylylene group, an isoindolylylene group, a benzofuranylylene group, a benzothiophenylylene group, a dibenzofuranylylene group, a dibenzothiophenylylene group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, and a pyridinylylene 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<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>1</sub>-C<sub>20</sub> 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 phenan-

threnyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenylylene group, a pentacenylylene group, a thiophenyl group, a furanyl group, a carbazolylylene group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, and a pyridinylylene group.

**[0242]** In one or more embodiments, R<sub>501</sub> and R<sub>501</sub> in Formula 502 may each independently be selected from

**[0243]** 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 hexacenylylene group, a pentacenylylene group, a thiophenyl group, a furanyl group, a carbazolylylene group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, and a pyridinylylene group; and

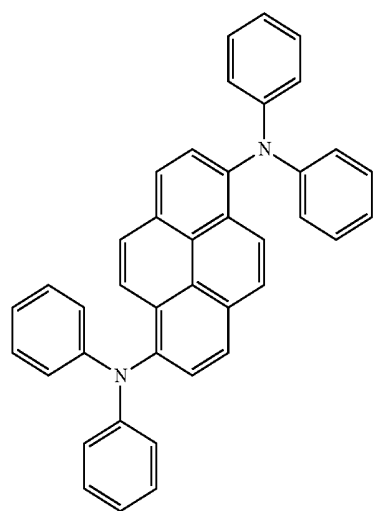
**[0244]** a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenylylene group, a pentacenylylene group, a thiophenyl group, a furanyl group, a carbazolylylene group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, and a pyridinylylene 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<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>1</sub>-C<sub>20</sub> 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 hexacenylylene group, a pentacenylylene group, a thiophenyl group, a furanyl group, a carbazolylylene group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, and a pyridinylylene group, and —Si(Q<sub>31</sub>)(Q<sub>32</sub>)(Q<sub>33</sub>),

**[0245]** wherein Q<sub>31</sub> to Q<sub>33</sub> may each independently be selected from a C<sub>1</sub>-C<sub>10</sub> alkyl group, a C<sub>1</sub>-C<sub>10</sub> alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

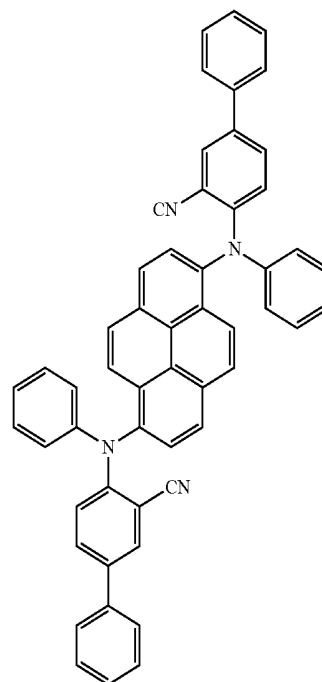
**[0246]** In one or more embodiments, xd4 in Formula 501 may be 2.

[0247] In some embodiments, the fluorescent dopant may be selected from Compounds FD1 to FD22:

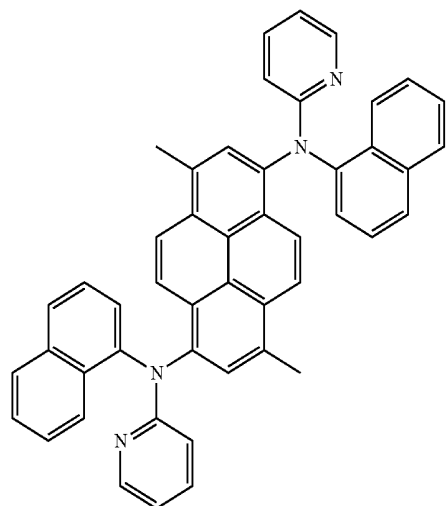
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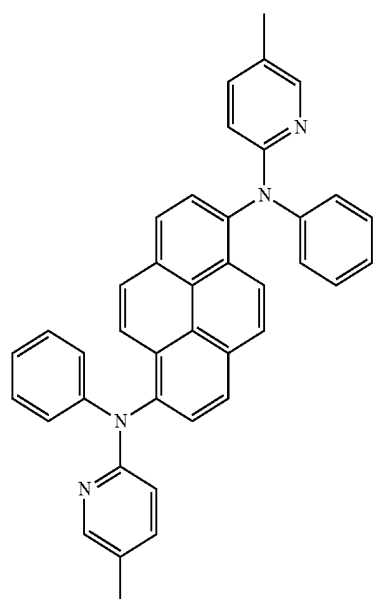
FD1



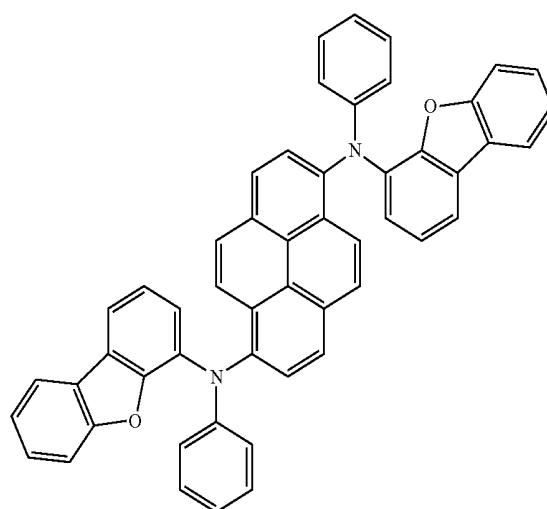
FD4



FD2



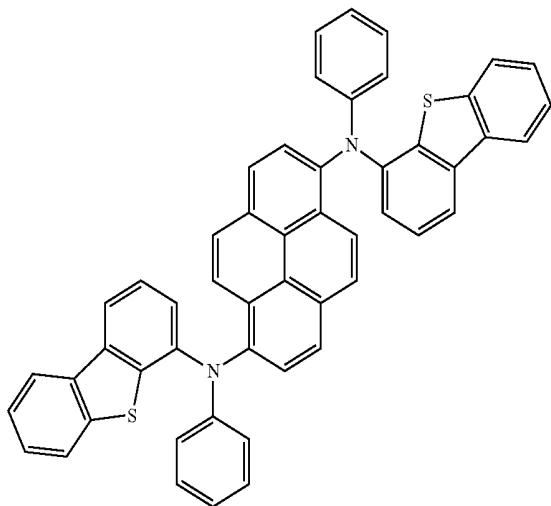
FD3



FD5

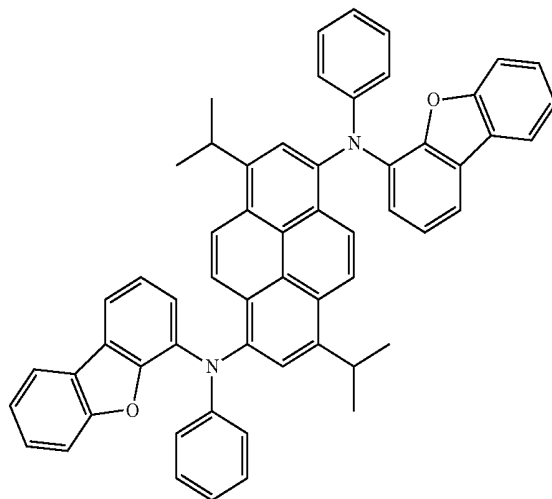
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FD6

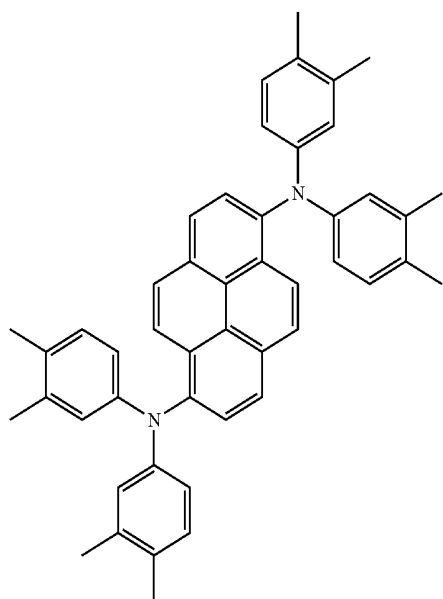


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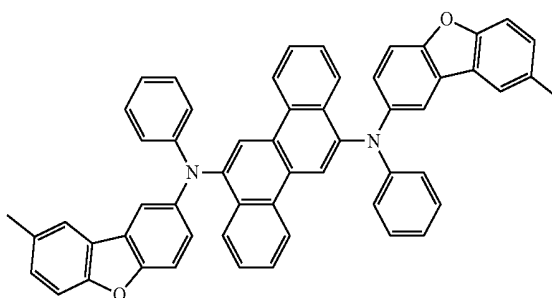
FD9



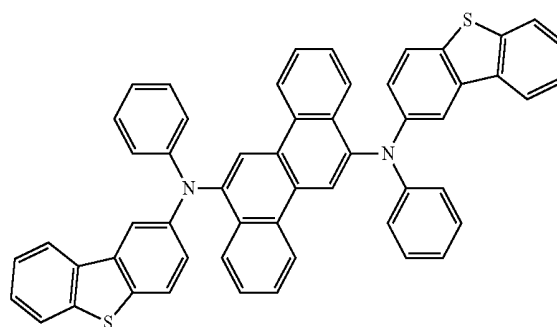
FD7



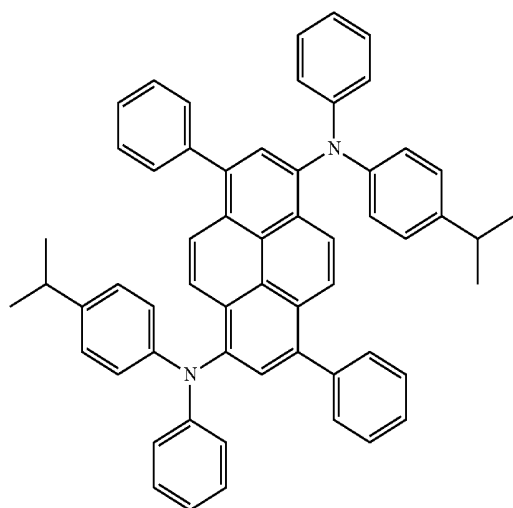
FD10



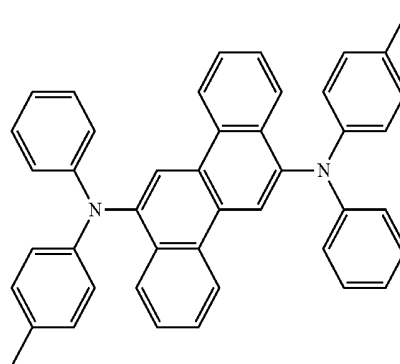
FD11



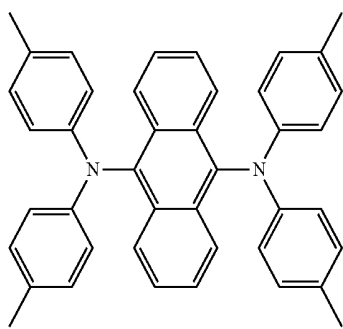
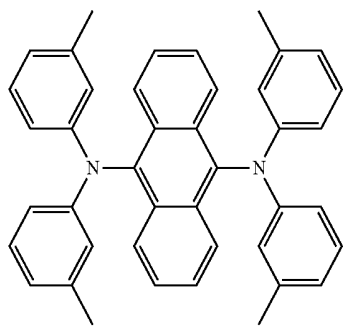
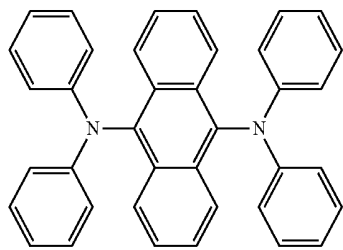
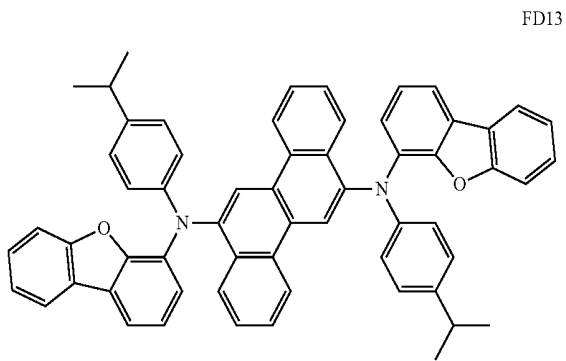
FD8



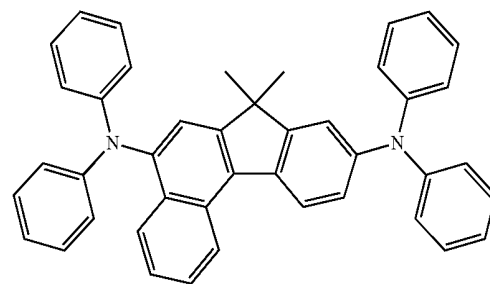
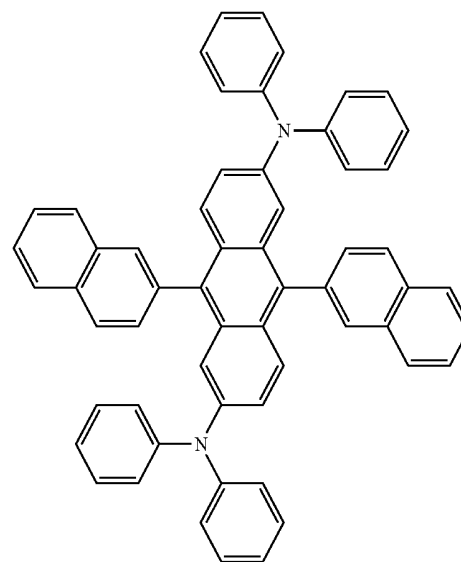
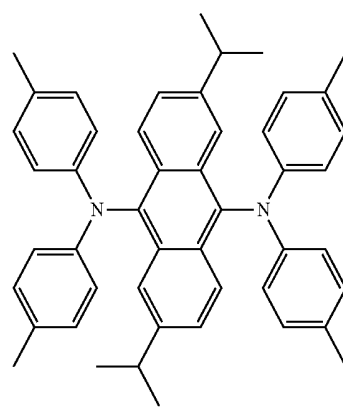
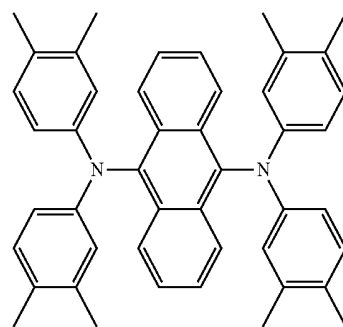
FD12



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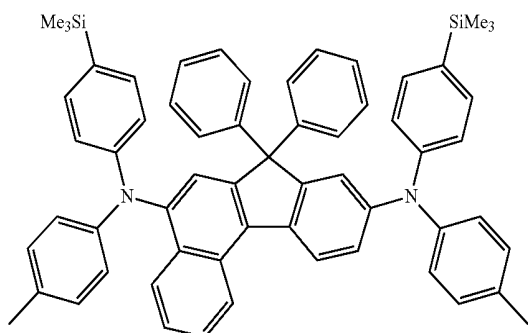


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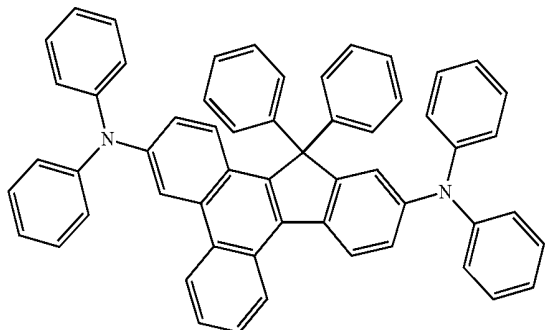
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FD21

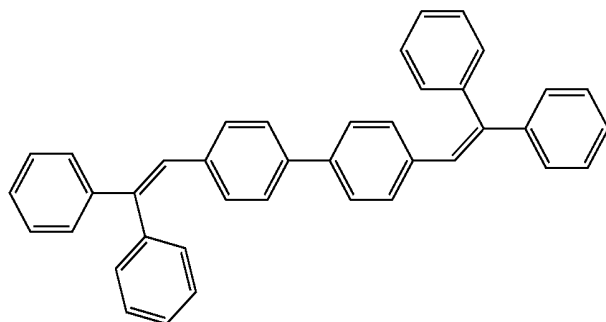


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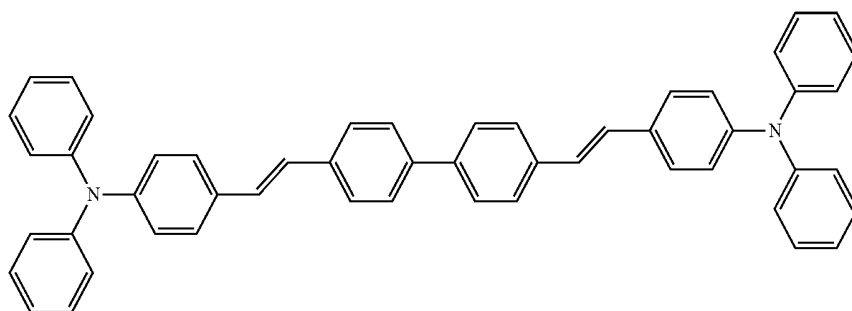
FD22



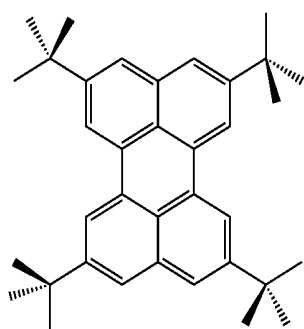
[0248] In one or more embodiments, the fluorescent dopant may be selected from the following compounds.



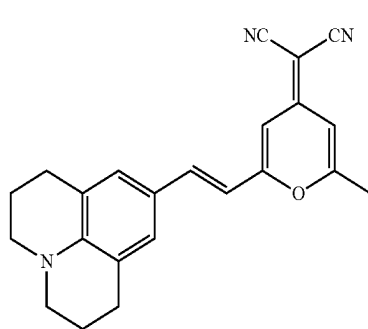
DPVBi



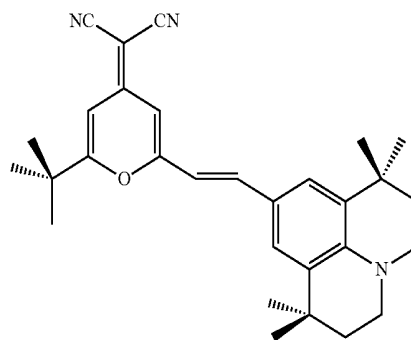
DPAVBi



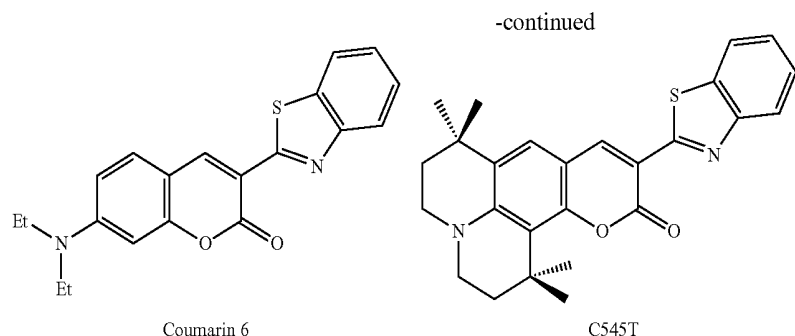
TBPe



DCM



DCJTb



[0249] 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.

[0250] In an implementation, 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.

[0251] 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 layers of each structure are sequentially stacked on an emission layer in each stated order.

[0252] The electron transport region (e.g., 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 including at least one  $\pi$  electron-depleted nitrogen-containing ring.

[0253] The term “ $\pi$  electron-depleted nitrogen-containing ring” as used herein refers to a  $C_1$ - $C_{60}$  heterocyclic group having at least one  $*-N=*'$  moiety as a ring-forming moiety.

[0254] For example, the  $\pi$  electron-depleted nitrogen-containing ring may be i) a 5-membered to 7-membered heteromonocyclic group having at least one  $*-N=*'$  moiety, ii) a heteropolycyclic group in which two or more 5-membered to 7-membered heteromonocyclic groups each having at least one  $*-N=*'$  moiety are condensed, or iii) a heteropolycyclic group in which at least one 5-membered to 7-membered heteromonocyclic group having at least one  $*-N=*'$  moiety is condensed with at least one  $C_5$ - $C_{60}$  carbocyclic group.

[0255] Examples of the  $\pi$  electron-depleted nitrogen-containing ring may include an imidazole, a pyrazole, a thiazole, an isothiazole, an oxazole, an isoxazole, a pyridine, a pyrazine, a pyrimidine, a pyridazine, an indazole, a purine, a quinoline, an isoquinoline, a benzoquinoline, a phthalazine, a naphthyridine, a quinoxaline, a quinazoline, a cinnoline, a phenanthridine, an acridine, a phenanthroline, a phenazine, a benzimidazole, an isobenzothiazole, a benzoxazole, an isobenzoxazole, a triazole, a tetrazole, an oxadiazole, a triazine, a thiadiazole, an imidazopyridine, an imidazopyrimidine, and an azacarbazole.

[0256] In some embodiments, the electron transport region may include a compound represented by Formula 601:



[0257] wherein, in Formula 601,

[0258]  $Ar_{601}$  may be a substituted or unsubstituted  $C_5$ - $C_{60}$  carbocyclic group or a substituted or unsubstituted  $C_1$ - $C_{60}$  heterocyclic group,

[0259]  $xe1$  may be 1, 2, or 3,

[0260]  $L_{601}$  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,

[0261]  $xe1$  may be an integer of 0 to 5,

[0262]  $R_{601}$  may be selected from a substituted or unsubstituted  $C_3$ - $C_{10}$  cycloalkyl group, a substituted or unsubstituted  $C_1$ - $C_{10}$  heterocycloalkyl group, a substituted or unsubstituted  $C_3$ - $C_{10}$  cycloalkenyl group, a substituted or unsubstituted  $C_1$ - $C_{10}$  heterocycloalkenyl group, a substituted or unsubstituted  $C_6$ - $C_{60}$  aryl group, a substituted or unsubstituted  $C_6$ - $C_{60}$  aryloxy group, a substituted or unsubstituted  $C_6$ - $C_{60}$  arylthio group, a substituted or unsubstituted  $C_1$ - $C_{60}$  heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group,  $-\text{Si}(Q_{601})(Q_{602})(Q_{603})$ ,  $-\text{C}(=\text{O})(Q_{601})$ ,  $-\text{S}(=\text{O})_2(Q_{601})$ , and  $-\text{P}(=\text{O})(Q_{610})(Q_{602})$ ,

[0263] wherein  $Q_{601}$  to  $Q_{603}$  may each independently be a  $C_1$ - $C_{10}$  alkyl group, a  $C_1$ - $C_{10}$  alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group, and

[0264]  $xe21$  may be an integer of 1 to 5.

[0265] In some embodiments, at least one of the  $xe1$   $Ar_{601}$  (s) and the  $xe21$  number of  $R_{601}$  (s) may include a  $\pi$  electron-depleted nitrogen-containing ring.

[0266] In some embodiments, ring  $Ar_{601}$  in Formula 601 may be selected from

[0267] a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran

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

[0268] a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, a dibenzothiophene group, a carbazole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, a naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, a phenanthroline group, a phenazine group, a benzimidazole group, an isobenzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a thiadiazole group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>1</sub>-C<sub>20</sub> alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, —Si(Q<sub>31</sub>)(Q<sub>32</sub>)(Q<sub>33</sub>), —S(=O)<sub>2</sub>(Q<sub>31</sub>), and —P(=O)(Q<sub>31</sub>)(Q<sub>32</sub>).

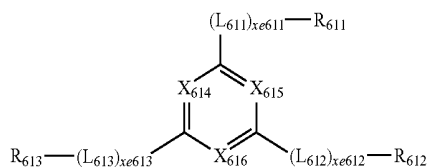
[0269] wherein Q<sub>31</sub> to Q<sub>33</sub> may each independently be selected from a C<sub>1</sub>-C<sub>10</sub> alkyl group, a C<sub>1</sub>-C<sub>10</sub> alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0270] When xe11 in Formula 601 is 2 or greater, a plurality of Ar<sub>601(s)</sub> may be bound via a single bond.

[0271] In one embodiment, Ar<sub>601</sub> in Formula 601 may be an anthracene group.

[0272] In some embodiments, the compound represented by Formula 601 may be represented by Formula 601-1:

Formula 601-1



[0273] wherein, in Formula 601-1,

[0274] X<sub>614</sub> may be N or C(R<sub>614</sub>), X<sub>615</sub> may be N or C(R<sub>615</sub>), X<sub>616</sub> may be N or C(R<sub>616</sub>), and at least one selected from X<sub>614</sub> to X<sub>616</sub> may be N,

[0275] descriptions of L<sub>611</sub> to L<sub>613</sub> may each independently be substantially the same as the description provided herein in connection with L<sub>601</sub>,

[0276] descriptions of xe611 to xe613 may each independently be substantially the same as the description provided herein in connection with xe1,

[0277] descriptions of R<sub>611</sub> to R<sub>613</sub> may each independently be substantially the same as the description provided herein in connection with R<sub>601</sub>, and

[0278] R<sub>614</sub> to R<sub>616</sub> 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<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>1</sub>-C<sub>20</sub> alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

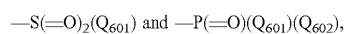
[0279] In one embodiment, L<sub>601</sub> and L<sub>611</sub> to L<sub>613</sub> in Formulae 601 and 601-1 may each independently be selected from

[0280] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylylene group, a fluoranthenylylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylylene group, a hexacenylylene group, a pentacenylylene group, a thiophenylylene group, a furanylylene group, a carbazolylylene group, an indolylylene group, an isoindolylylene group, a benzofuranylylene group, a benzothiophenylylene group, a dibenzofuranylylene group, a dibenzothiophenylylene group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, a pyridinylylene group, an imidazolylylene group, a pyrazolylylene group, a thiazolylylene group, an isothiazolylylene group, an oxazolylylene group, an isoxazolylylene group, a thiadiazolylylene group, an oxadiazolylylene group, a pyrazinylylene group, a pyrimidinylylene group, a pyridazinylylene group, a triazinylylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylylene group, an isobenzothiazolylylene group, a benzoxazolylylene group, an isobenzoxazolylylene group, a triazolylylene group, a tetrazolylylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolylylene group; and

[0281] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylylene group, a benzofluorenylylene group, a dibenzofluorenylylene group, a phenanthrenylene group, an anthracenylylene group, a fluoranthenylylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylylene group, a hexacenylylene group, a pentacenylylene group, a thiophenylylene group, a furanylylene group, a carbazolylylene group, an indolylylene group, an isoindolylylene group, a benzofuranylylene group, a benzothiophenylylene group, a dibenzofuranylylene group, a dibenzothiophenylylene group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, a pyridinylylene group, an imidazolylylene group, a pyrazolylylene group, a thiazolylylene group,



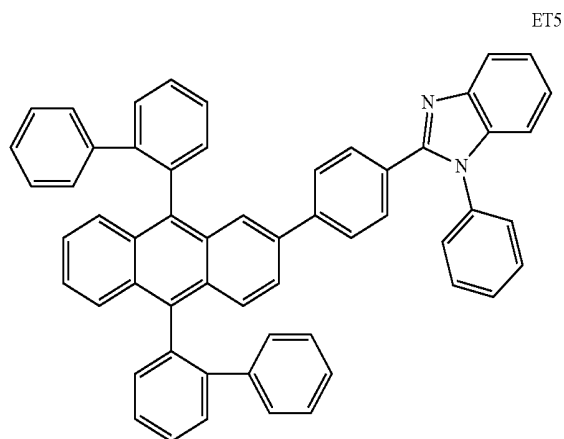
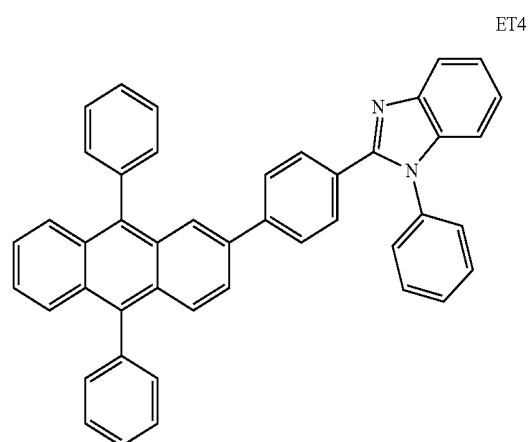
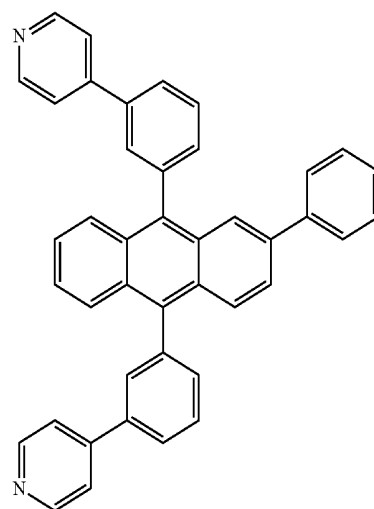
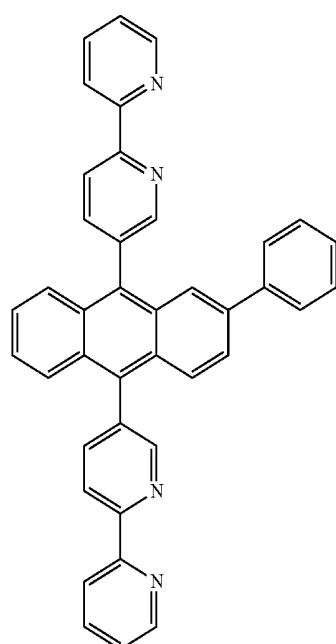
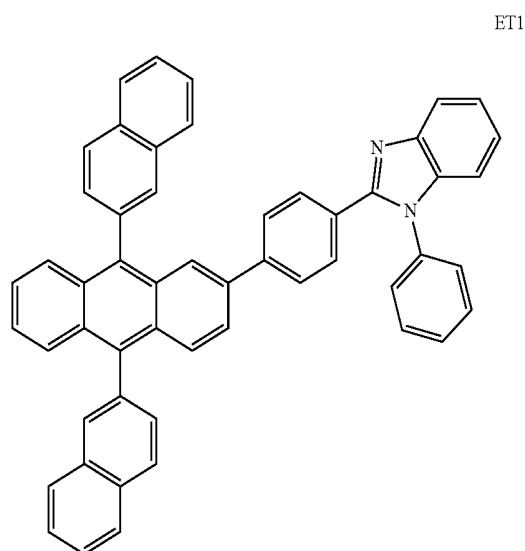
cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenaziny group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group; and



[0286] wherein descriptions of  $\text{Q}_{601}$  and  $\text{Q}_{602}$  may each independently be substantially the same as descriptions thereof provided herein.

[0287] The electron transport region may include at least one compound selected from Compounds ET1 to ET36.

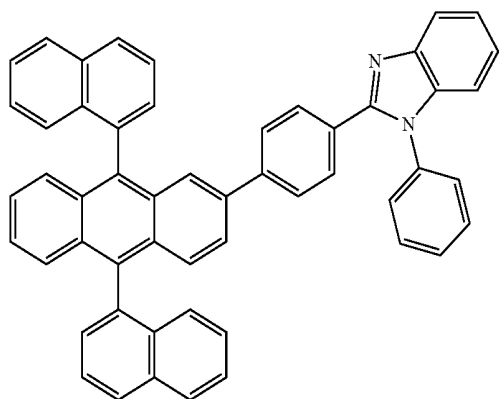
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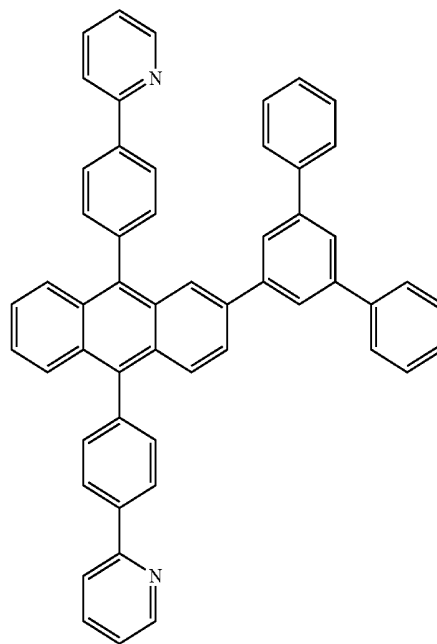
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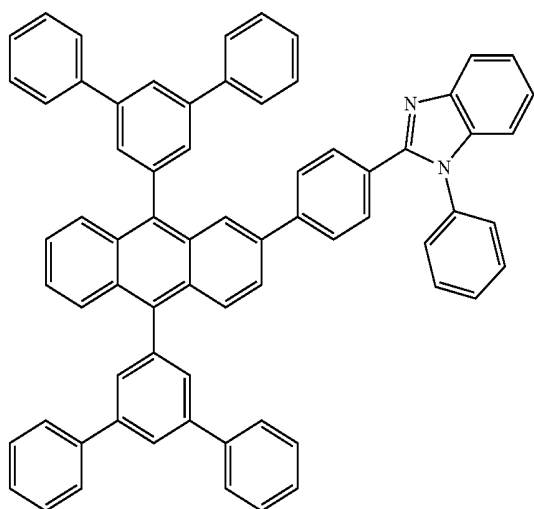
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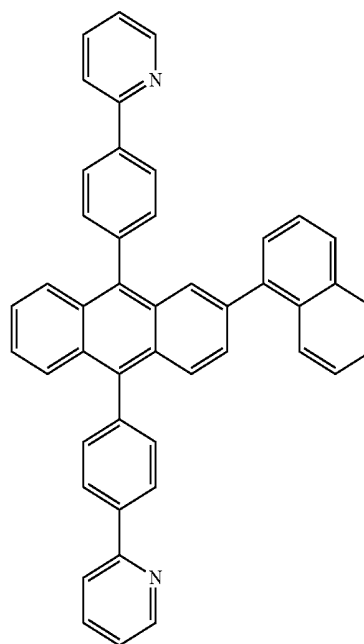
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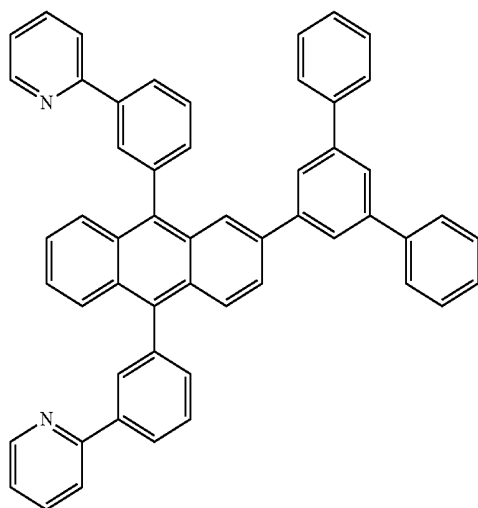
ET7



ET10

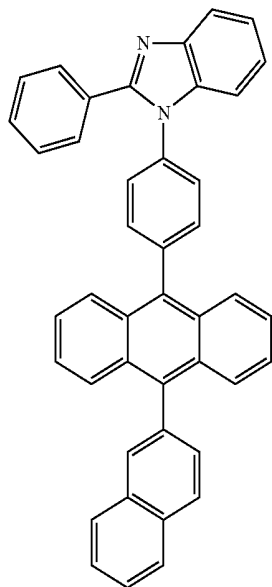


ET8



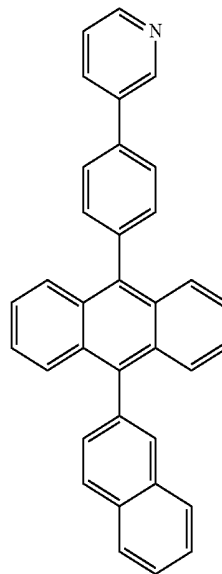


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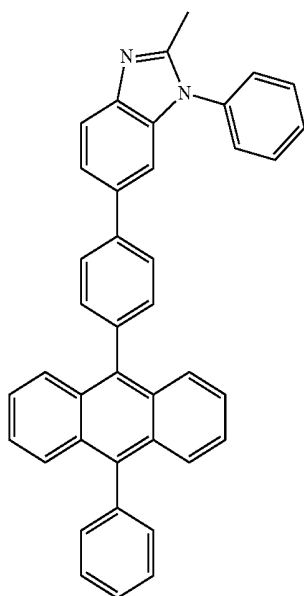
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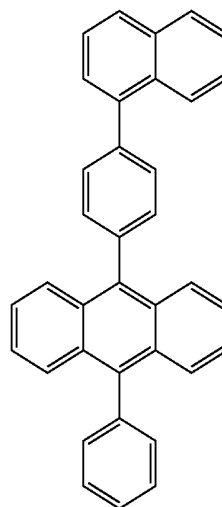


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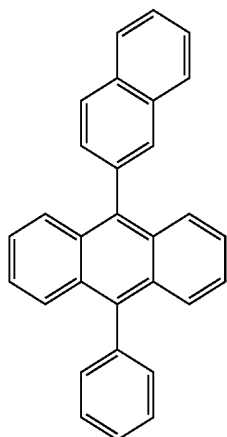
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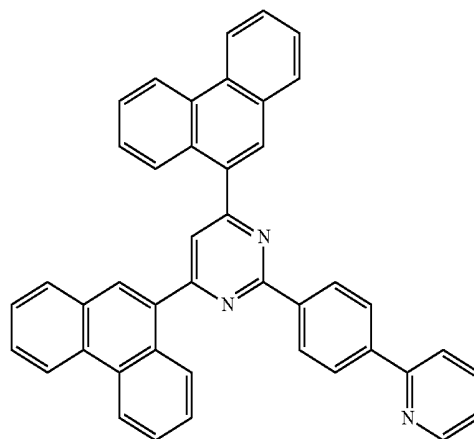
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ET19

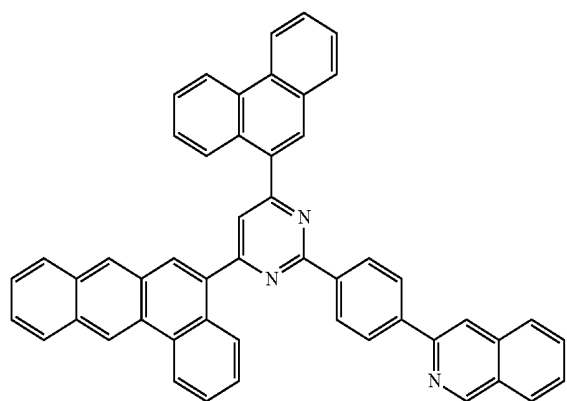


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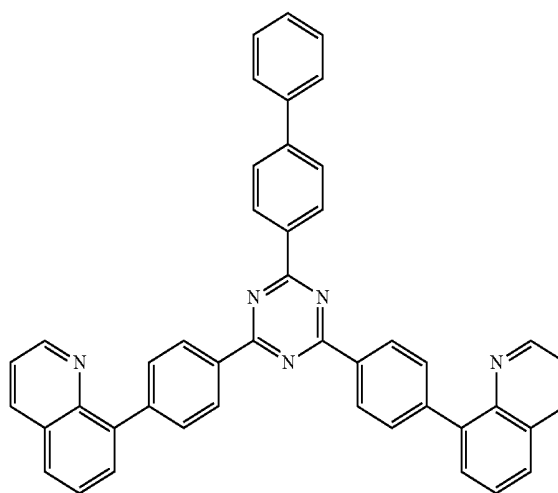
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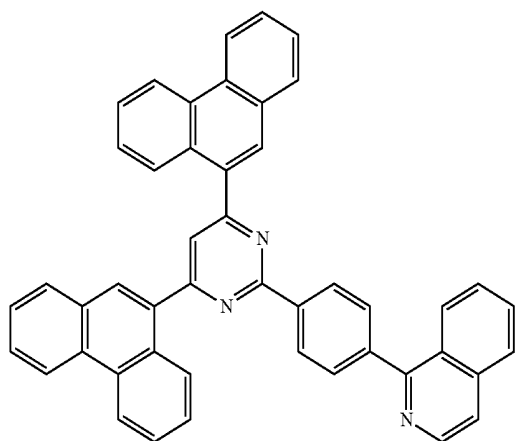


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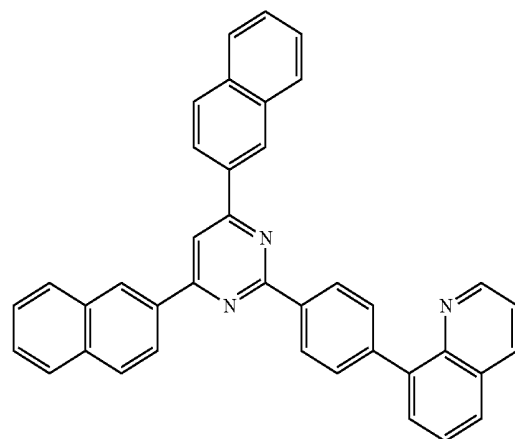
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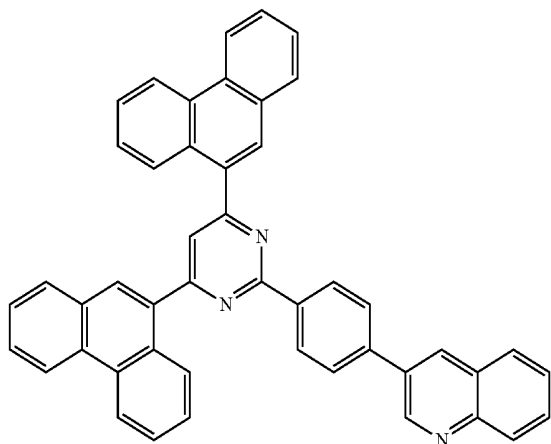
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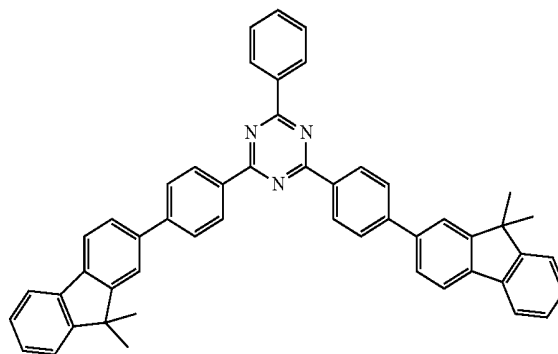
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ET27

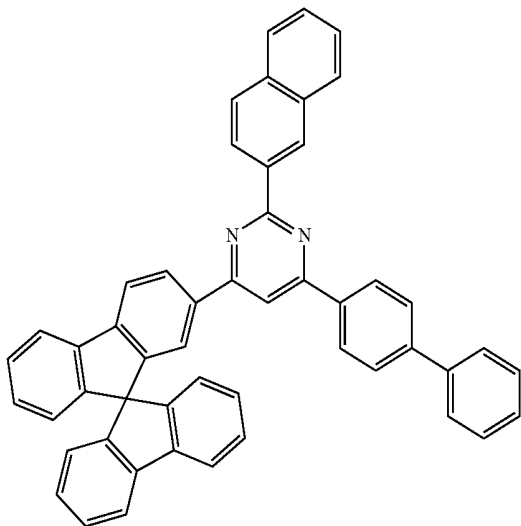


ET28



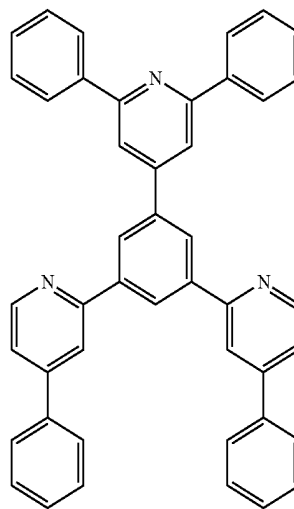
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ET29

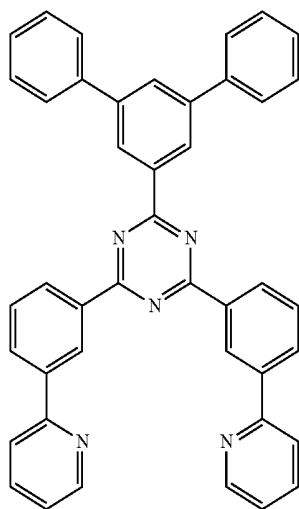


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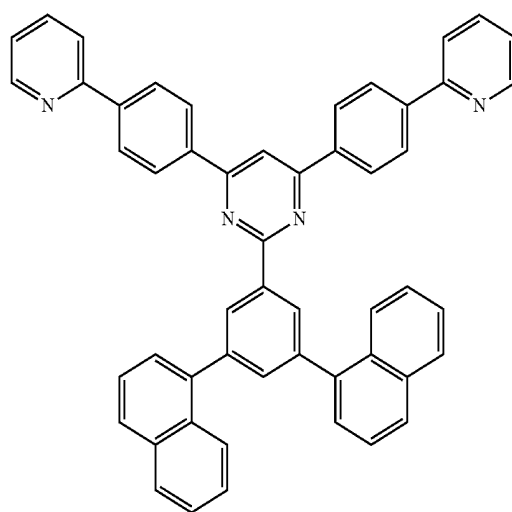
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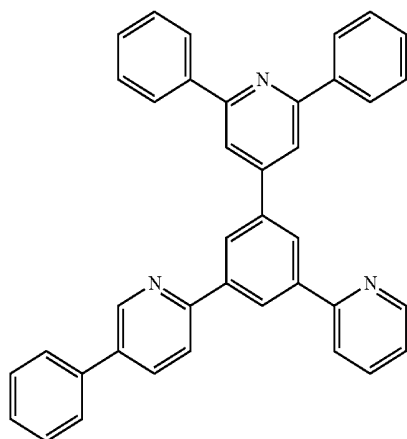
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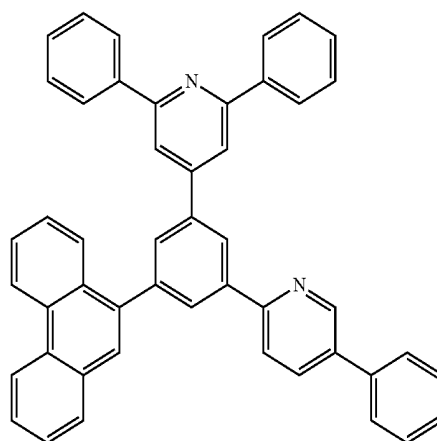
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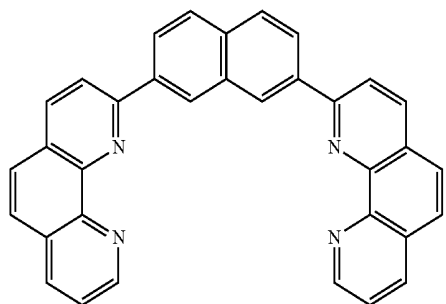
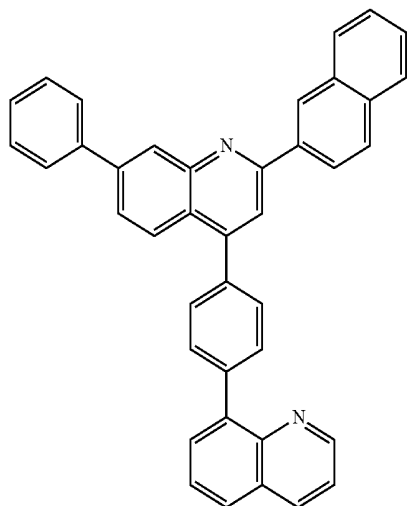
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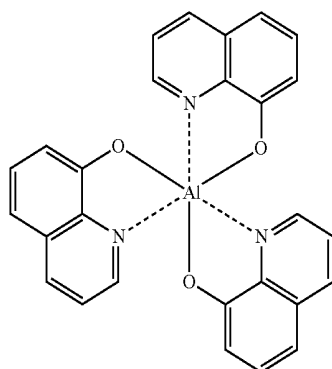
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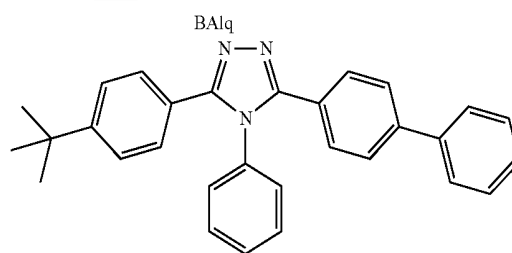
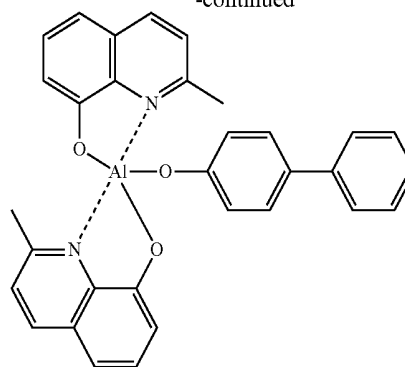


[0288] In one or more embodiments, the electron transport region may include at least one selected from 2,9-dimethyl-4,7-diphenyl-1, 10-phenanthroline (BCP), 4,7-diphenyl-1, 10-phenanthroline (Bphen), Alq<sub>3</sub>, BAlq, 3-(biphenyl-4-yl)-5-(4-tert-butylphenyl)-4-phenyl-4H-1,2,4-triazole (TAZ), and NTAZ:

Alq<sub>3</sub>

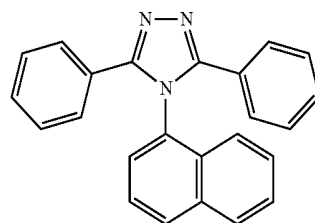
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ET35



TAZ

ET36



NTAZ

[0289] Thicknesses of the buffer layer, the hole blocking layer, and the electron control layer may each be in a range of about 20 Å to about 1,000 Å, e.g., about 30 Å to about 300 Å. When the thicknesses of the buffer layer, the hole blocking layer, and the electron control layer are each within any of these ranges, the electron transport region may have excellent electron blocking characteristics or electron control characteristics without a substantial increase in driving voltage.

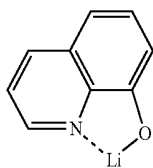
[0290] The thickness of the electron transport layer may be in a range of about 100 Å to about 1,000 Å, e.g., about 150 Å to about 500 Å. When the thickness of the electron transport layer is within any of these ranges, the electron transport layer may have satisfactory electron transport characteristics without a substantial increase in driving voltage.

[0291] The electron transport region (e.g., the electron transport layer in the electron transport region) may further include, in addition to the materials described above, a metal-containing material.

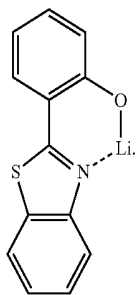
[0292] The metal-containing material may include at least one selected from an alkali metal complex and an alkaline earth-metal complex. The alkali metal complex may include a metal ion selected from a Li ion, a Na ion, a K ion, an Rb ion, and a Cs ion. The alkaline earth-metal complex may include a metal ion selected from a Be ion, an Mg ion, a Ca ion, an Sr ion, and a Ba ion. Ligands respectively coordinated with the metal ion of the alkali metal complex or the alkaline earth-metal complex may each independently be

selected from a hydroxyquinoline, a hydroxyisoquinoline, a hydroxybenzoquinoline, a hydroxyacridine, a hydroxyphenanthridine, a hydroxyphenyl oxazole, a hydroxyphenyl thiazole, a hydroxydiphenyl oxadiazole, a hydroxydiphenyl thiadiazole, a hydroxyphenyl pyridine, a hydroxyphenyl benzimidazole, a hydroxyphenyl benzothiazole, a bipyridine, a phenanthroline, and a cyclopentadiene.

[0293] In some embodiments, 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

[0294] The electron transport region may include an electron injection layer that facilitates the injection of electrons from the second electrode **190**. The electron injection layer may directly contact the second electrode **190**.

[0295] 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.

[0296] The electron injection layer may include an alkali metal, an alkaline earth-metal, a rare-earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare-earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare-earth metal complex, or a combination thereof.

[0297] The alkali metal may be selected from Li, Na, K, Rb, and Cs. In one embodiment, the alkali metal may be Li, Na, or Cs. In one or more embodiments, the alkali metal may be Li or Cs.

[0298] The alkaline earth-metal may be selected from Mg, Ca, Sr, and Ba.

[0299] The rare-earth metal may be selected from Sc, Y, Ce, Yb, Gd, and Tb.

[0300] The alkali metal compound, the alkaline earth-metal compound, and the rare-earth metal compound may each independently be selected from oxides and halides (e.g., fluorides, chlorides, bromides, or iodides) of the alkali metal, the alkaline earth-metal, and the rare-earth metal, respectively.

[0301] The alkali metal compound may be selected from alkali metal oxides, such as  $\text{Li}_2\text{O}$ ,  $\text{Cs}_2\text{O}$ , or  $\text{K}_2\text{O}$ , and alkali metal halides, such as LiF, NaF, CsF, KF, LiI, NaI, CsI, KI,

or RbI. In one embodiment, the alkali metal compound may be selected from LiF,  $\text{Li}_2\text{O}$ , NaF, LiI, NaI, CsI, and KI.

[0302] The alkaline earth-metal compound may be selected from alkaline earth-metal compounds, such as BaO, SrO, CaO,  $\text{Ba}_x\text{Sr}_{1-x}\text{O}$  (wherein  $0 < x < 1$ ), or  $\text{Ba}_x\text{Ca}_{1-x}\text{O}$  (wherein  $0 < x < 1$ ). In one embodiment, the alkaline earth-metal compound may be selected from BaO, SrO, and CaO.

[0303] The rare-earth metal compound may be selected from  $\text{YbF}_3$ ,  $\text{ScF}_3$ ,  $\text{ScO}_3$ ,  $\text{Y}_2\text{O}_3$ ,  $\text{Ce}_2\text{O}_3$ ,  $\text{GdF}_3$ , and  $\text{TbF}_3$ . In one embodiment, the rare-earth metal compound may be selected from  $\text{YbF}_3$ ,  $\text{ScF}_3$ ,  $\text{TbF}_3$ ,  $\text{YbI}_3$ ,  $\text{ScI}_3$ , and  $\text{TbI}_3$ .

[0304] The alkali metal complex, the alkaline earth-metal complex, and the rare-earth metal complex may include an alkali metal ion, and an alkaline earth-metal ion, and a rare-earth metal ion, respectively, as described above, and ligands respectively coordinated with the metal ion of the alkali metal complex, the alkaline earth-metal complex, and the rare-earth metal complex may each independently be selected from a hydroxyquinoline, a hydroxyisoquinoline, a hydroxybenzoquinoline, a hydroxyacridine, a hydroxyphenanthridine, a hydroxyphenyl oxazole, a hydroxyphenyl thiazole, a hydroxydiphenyl oxadiazole, a hydroxydiphenyl thiadiazole, a hydroxyphenyl pyridine, a hydroxyphenyl benzimidazole, a hydroxyphenyl benzothiazole, a bipyridine, a phenanthroline, and a cyclopentadiene.

[0305] The electron injection layer may include an alkali metal, an alkaline earth-metal, a rare-earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare-earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare-earth metal complex, or a combination thereof, as described above. In one or more embodiments, the electron injection layer may further include an organic material. When the electron injection layer further includes an organic material; an alkali metal, an alkaline earth-metal, a rare-earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare-earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare-earth metal complex, or a combination thereof may be homogeneously or non-homogeneously dispersed in a matrix including the organic material.

[0306] The thickness of the electron injection layer may be in a range of about 1 Å to about 100 Å, e.g., about 3 Å to about 90 Å. When the thickness of the electron injection layer is within any of these ranges, the electron injection layer may have satisfactory electron injection characteristics without a substantial increase in driving voltage.

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

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

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

[0310] An organic light-emitting device **20** illustrated in 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** illustrated in 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** illustrated in 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**.

[0311] Regarding FIGS. 2 to 4, the first electrode **110**, the organic layer **150**, and the second electrode **190** may each independently be the same as those described above in connection with FIG. 1.

[0312] In the organic layer **150** of each of the organic light-emitting devices **20** and **40**, light emitted from the emission layer may pass through the first electrode **110**, which is a semi-transmissive electrode or a transmissive electrode, and through 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 emitted from the emission layer may pass through the second electrode **190**, which is a semi-transmissive electrode or a transmissive electrode, and through the second capping layer **220** toward the outside.

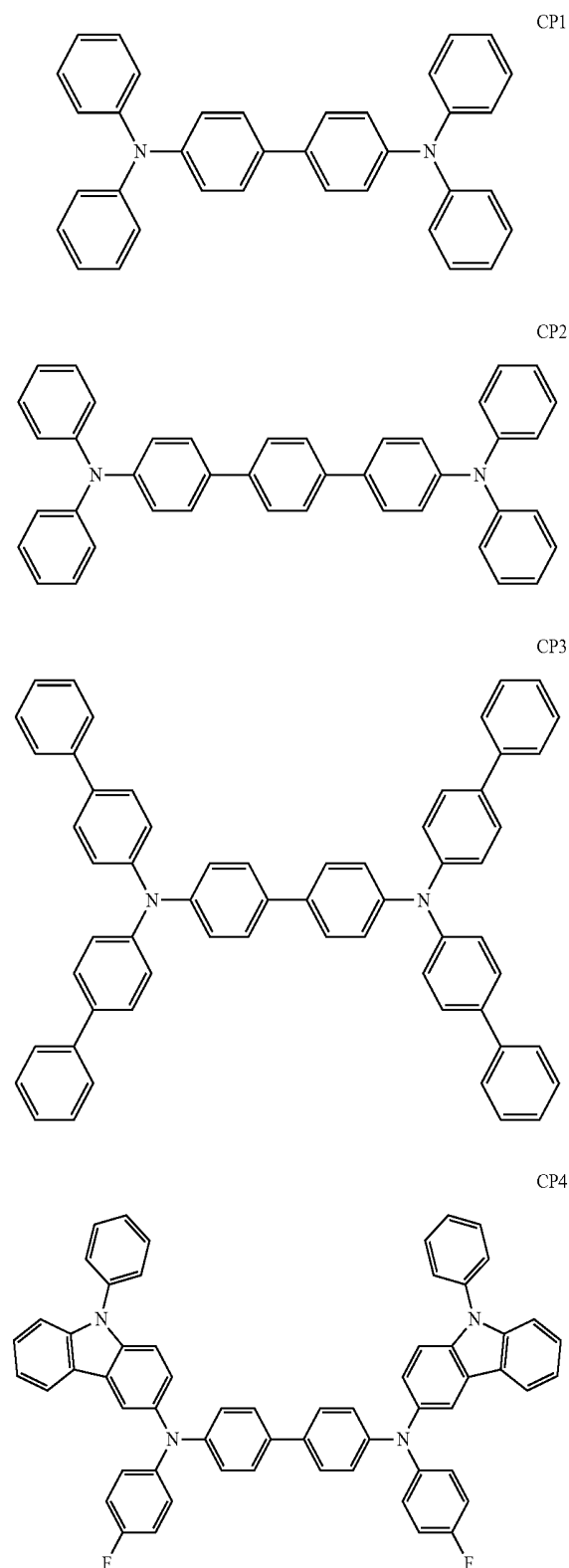
[0313] The first capping layer **210** and the second capping layer **220** may help increase external luminescent efficiency, based on the principle of constructive interference.

[0314] 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.

[0315] In an implementation, 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 the condensed-cyclic compound represented by Formula 1, carbocyclic compounds, heterocyclic compounds, amine-based compounds, porphine derivatives, phthalocyanine derivatives, naphthalocyanine derivatives, alkali metal complexes, and alkaline earth-metal complexes. The carbocyclic compound, the heterocyclic compound, and the amine-based compound may optionally be substituted with a substituent including at least one element selected from O, N, S, selenium (Se), silicon (Si), fluorine (F), chlorine (Cl), bromine (Br), and iodine (I). In one embodiment, at least one selected from the first capping layer **210** and the second capping layer **220** may include an amine-based compound.

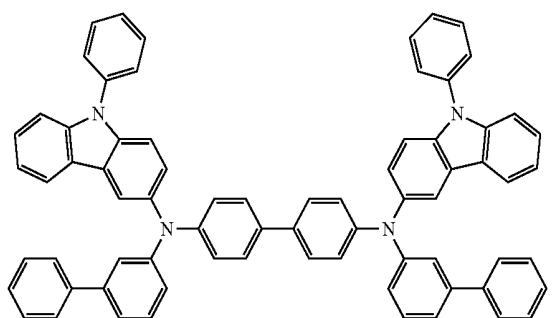
[0316] In one embodiment, at least one selected from the first capping layer **210** and the second capping layer **220** may include the compound represented by Formula 201 or the compound represented by Formula 202.

[0317] In one or more embodiments, at least one selected from the first capping layer **210** and the second capping layer **220** may include a compound selected from Compounds HT28 to HT33 and Compounds CP1 to CP5.



-continued

CP5



[0318] Hereinbefore, an organic light-emitting device according to one or more embodiment has been described in connection with FIGS. 1 to 4.

[0319] The layers constituting the hole transport region, the emission layer, and the layers constituting the electron transport region may be formed in a specific region 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 (LITI).

[0320] When the layers constituting the hole transport region, the emission layer, and the layers constituting the electron transport region are each formed by vacuum deposition, the vacuum deposition may be performed, for example, at a deposition temperature of about 100° C. to about 500° C., at a vacuum degree of about 10<sup>-2</sup> torr to about 10<sup>-3</sup> torr, and at a deposition rate of about 0.01 Angstroms per second (Å/sec) to about 100 Å/sec, depending on the compound to be included in each layer and the structure of each layer to be formed.

[0321] When the layers constituting the hole transport region, the emission layer, and the layers constituting the electron transport region are formed by spin coating, the spin coating may be performed, for example, at a coating rate of about 2,000 revolutions per minute (rpm) to about 5,000 rpm and at a heat treatment temperature of about 80° C. to 200° C., depending on the compound to be included in each layer and the structure of each layer to be formed.

[0322] The term “C<sub>1</sub>-C<sub>60</sub> alkyl group” as used herein refers to a linear or branched aliphatic saturated hydrocarbon monovalent group having 1 to 60 carbon atoms. Examples thereof may include a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, a pentyl group, an iso-amyl group, and a hexyl group. The term “C<sub>1</sub>-C<sub>60</sub> alkylene group” as used herein refers to a divalent group having the same structure as the C<sub>1</sub>-C<sub>60</sub> alkyl group.

[0323] The term “C<sub>2</sub>-C<sub>60</sub> alkenyl group” as used herein refers to a hydrocarbon group having at least one carbon-carbon double bond in the middle or at the terminus of the C<sub>2</sub>-C<sub>60</sub> alkyl group. Examples thereof may include an ethenyl group, a propenyl group, and a butenyl group. The term “C<sub>2</sub>-C<sub>60</sub> alkenylene group” as used herein refers to a divalent group having the same structure as the C<sub>2</sub>-C<sub>60</sub> alkenyl group.

[0324] The term “C<sub>2</sub>-C<sub>60</sub> alkynyl group” as used herein refers to a hydrocarbon group having at least one carbon-carbon triple bond in the middle or at the terminus of the C<sub>2</sub>-C<sub>60</sub> alkyl group. Examples thereof may include an ethynyl group and a propynyl group.

The term “C<sub>2</sub>-C<sub>60</sub> alkynylene group” as used herein refers to a divalent group having the same structure as the C<sub>2</sub>-C<sub>60</sub> alkynyl group.

[0325] The term “C<sub>1</sub>-C<sub>60</sub> alkoxy group” as used herein refers to a monovalent group represented by —OA<sub>101</sub> (wherein A<sub>101</sub> is the C<sub>1</sub>-C<sub>60</sub> alkyl group). Examples thereof may include a methoxy group, an ethoxy group, and an isopropoxy group.

[0326] The term “C<sub>3</sub>-C<sub>10</sub> cycloalkyl group” as used herein refers to a monovalent saturated hydrocarbon monocyclic group having 3 to 10 carbon atoms. Examples thereof may include a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. The term “C<sub>3</sub>-C<sub>10</sub> cycloalkylene group” as used herein refers to a divalent group having the same structure as the C<sub>3</sub>-C<sub>10</sub> cycloalkyl group.

[0327] The term “C<sub>1</sub>-C<sub>10</sub> 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. Examples thereof may include a 1,2,3,4-oxatriazolidinyl group, a tetrahydrofuranyl group, and a tetrahydrothiophenyl group. The term “C<sub>1</sub>-C<sub>10</sub> heterocycloalkylene group” as used herein refers to a divalent group having the same structure as the C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group.

[0328] The term “C<sub>3</sub>-C<sub>10</sub> 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 is not aromatic. Examples thereof may include a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. The term “C<sub>3</sub>-C<sub>10</sub> cycloalkenylene group” as used herein refers to a divalent group having the same structure as the C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group.

[0329] The term “C<sub>1</sub>-C<sub>10</sub> 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. Examples of the C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group may include a 4,5-dihydro-1,2,3,4-oxatriazolyl group, a 2,3-dihydrofuranyl group, and a 2,3-dihydrothiophenyl group. The term “C<sub>1</sub>-C<sub>10</sub> heterocycloalkenylene group” as used herein refers to a divalent group having the same structure as the C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group.

[0330] The term “C<sub>6</sub>-C<sub>60</sub> aryl group” as used herein refers to a monovalent group that has a carbocyclic aromatic system having 6 to 60 carbon atoms. The term “C<sub>6</sub>-C<sub>60</sub> arylene group” as used herein refers to a divalent group that has a carbocyclic aromatic system having 6 to 60 carbon atoms. Examples of the C<sub>6</sub>-C<sub>60</sub> aryl group may include a phenyl group, a naphthyl group, an anthracenyl group, a phenanthrenyl group, a pyrenyl group, and a chrysenyl group. When the C<sub>6</sub>-C<sub>60</sub> aryl group and the C<sub>6</sub>-C<sub>60</sub> arylene group each include two or more rings, the rings may be fused.

[0331] The term “C<sub>1</sub>-C<sub>60</sub> heteroaryl group” as used herein refers to a monovalent group having an aromatic system that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, in addition to 1 to 60 carbon atoms. The term “C<sub>1</sub>-C<sub>60</sub> heteroarylene group” as used herein refers to a divalent group having an 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.

Examples of the C<sub>1</sub>-C<sub>60</sub> heteroaryl group may include a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, and an isoquinolinyl group. When the C<sub>1</sub>-C<sub>60</sub> heteroaryl group and the C<sub>1</sub>-C<sub>60</sub> heteroarylene group each include two or more rings, the rings may be fused.

**[0332]** The term “C<sub>6</sub>-C<sub>60</sub> aryloxy group” as used herein refers to —OA<sub>102</sub> (wherein A<sub>102</sub> is a C<sub>6</sub>-C<sub>60</sub> aryl group). The term “C<sub>6</sub>-C<sub>60</sub> arylthio group” as used herein refers to —SA<sub>103</sub> (wherein A<sub>103</sub> is a C<sub>6</sub>-C<sub>60</sub> aryl group).

**[0333]** The term “monovalent non-aromatic condensed polycyclic group” as used herein refers to a monovalent group that has two or more rings condensed and only carbon atoms (e.g., 8 to 60 carbon atoms) as ring-forming atoms, wherein the entire molecular structure is non-aromatic. Examples of the monovalent non-aromatic condensed polycyclic group may include 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.

**[0334]** The term “monovalent non-aromatic condensed heteropolycyclic group” as used herein refers to a monovalent group that has two or more rings condensed, at least one heteroatom selected from N, O, Si, P, and S, in addition to carbon atoms (e.g., 1 to 60 carbon atoms), as ring-forming atoms, wherein the entire molecular structure is non-aromatic. Examples of the monovalent non-aromatic condensed heteropolycyclic group may include a carbazolyl group. The term “divalent non-aromatic condensed heteropolycyclic group” as used herein refers to a divalent group having the same structure as the monovalent non-aromatic condensed heteropolycyclic group.

**[0335]** The term “C<sub>5</sub>-C<sub>60</sub> carbocyclic group” as used herein refers to a monocyclic or polycyclic group having 5 to 60 carbon atoms as the only ring-forming atoms. The C<sub>5</sub>-C<sub>60</sub> carbocyclic group may be an aromatic carbocyclic group or a non-aromatic carbocyclic group. The C<sub>5</sub>-C<sub>60</sub> 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 C<sub>5</sub>-C<sub>60</sub> carbocyclic group, the C<sub>5</sub>-C<sub>60</sub> carbocyclic group may be a trivalent group or a quadrivalent group.

**[0336]** The term “C<sub>1</sub>-C<sub>60</sub> heterocyclic group” as used herein refers to a group having substantially the same structure as the C<sub>1</sub>-C<sub>60</sub> carbocyclic group, except that as a ring-forming atom, at least one heteroatom selected from N, O, Si, P, and S may be used in addition to carbon atoms (e.g., 1 to 60 carbon atoms).

**[0337]** In the present specification, at least one of substituents of the substituted C<sub>5</sub>-C<sub>60</sub> carbocyclic group, substituted C<sub>1</sub>-C<sub>60</sub> heterocyclic group, substituted C<sub>3</sub>-C<sub>10</sub> cycloalkylene group, substituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkylene group, substituted C<sub>3</sub>-C<sub>10</sub> cycloalkenylene group, substituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkenylene group, substituted C<sub>6</sub>-C<sub>60</sub> arylene group, substituted C<sub>1</sub>-C<sub>60</sub> heteroarylene group, substituted divalent non-aromatic condensed polycyclic group, substituted divalent non-aromatic condensed heteropolycyclic group, substituted C<sub>1</sub>-C<sub>60</sub> alkyl group, substituted C<sub>2</sub>-C<sub>60</sub> alkenyl group, substituted C<sub>2</sub>-C<sub>60</sub> alkynyl group, substituted C<sub>1</sub>-C<sub>60</sub> alkoxy group, substituted C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, substituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, substituted C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, substituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, substituted C<sub>6</sub>-C<sub>60</sub> aryl group, substituted C<sub>6</sub>-C<sub>60</sub> aryloxy group, substituted C<sub>6</sub>-C<sub>60</sub> arylthio group, substituted C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from:

deuterium (-D), —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C<sub>1</sub>-C<sub>60</sub> alkyl group, a C<sub>2</sub>-C<sub>60</sub> alkenyl group, a C<sub>2</sub>-C<sub>60</sub> alkynyl group, and a C<sub>1</sub>-C<sub>60</sub> alkoxy group;

**[0338]** deuterium (-D), —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C<sub>1</sub>-C<sub>60</sub> alkyl group, a C<sub>2</sub>-C<sub>60</sub> alkenyl group, a C<sub>2</sub>-C<sub>60</sub> alkynyl group, and a C<sub>1</sub>-C<sub>60</sub> alkoxy group;

**[0339]** a C<sub>1</sub>-C<sub>60</sub> alkyl group, a C<sub>2</sub>-C<sub>60</sub> alkenyl group, a C<sub>2</sub>-C<sub>60</sub> alkynyl group, and a C<sub>1</sub>-C<sub>60</sub> alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>6</sub>-C<sub>60</sub> aryloxy group, a C<sub>6</sub>-C<sub>60</sub> arylthio group, a C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —Si(Q)(Q<sub>11</sub>)(Q<sub>12</sub>)(Q<sub>13</sub>), —N(Q<sub>11</sub>)(Q<sub>12</sub>), —B(Q<sub>11</sub>)(Q<sub>12</sub>), —C(=O)(Q<sub>11</sub>), —S(=O)<sub>2</sub>(Q<sub>11</sub>), and —P(=O)(Q<sub>11</sub>)(Q<sub>12</sub>);

**[0340]** a C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>6</sub>-C<sub>60</sub> aryloxy group, a C<sub>6</sub>-C<sub>60</sub> arylthio group, a C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

**[0341]** a C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>6</sub>-C<sub>60</sub> aryloxy group, a C<sub>6</sub>-C<sub>60</sub> arylthio group, a C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C<sub>1</sub>-C<sub>60</sub> alkyl group, a C<sub>2</sub>-C<sub>60</sub> alkenyl group, a C<sub>2</sub>-C<sub>60</sub> alkynyl group, a C<sub>1</sub>-C<sub>60</sub> alkoxy group, a C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>6</sub>-C<sub>60</sub> aryloxy group, a C<sub>6</sub>-C<sub>60</sub> arylthio group, a C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —Si(Q<sub>21</sub>)(Q<sub>22</sub>)(Q<sub>23</sub>), —N(Q<sub>21</sub>)(Q<sub>22</sub>), —B(Q<sub>21</sub>)(Q<sub>22</sub>), —C(=O)(Q<sub>21</sub>), —S(=O)<sub>2</sub>(Q<sub>21</sub>), and —P(=O)(Q<sub>21</sub>)(Q<sub>22</sub>); and

**[0342]** —Si(Q<sub>31</sub>)(Q<sub>32</sub>)(Q<sub>33</sub>), —N(Q<sub>31</sub>)(Q<sub>32</sub>), —B(Q<sub>31</sub>)(Q<sub>32</sub>), —C(=O)(Q<sub>31</sub>), —S(=O)<sub>2</sub>(Q<sub>31</sub>), and —P(=O)(Q<sub>31</sub>)(Q<sub>32</sub>).

**[0343]** wherein Q<sub>1</sub> to Q<sub>3</sub>, Q<sub>11</sub> to Q<sub>13</sub>, Q<sub>21</sub> to Q<sub>23</sub>, and Q<sub>31</sub> to Q<sub>33</sub> 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<sub>1</sub>-C<sub>60</sub> alkyl group, a C<sub>2</sub>-C<sub>60</sub> alkenyl group, a C<sub>2</sub>-C<sub>60</sub> alkynyl group, a C<sub>1</sub>-C<sub>60</sub> alkoxy group, a C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a

monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

[0344] The term “Ph” as used herein represents a phenyl group. The term “Me” as used herein represents a methyl group. The term “Et” as used herein represents ethyl group. The term “ter-Bu” or “Bu” as used herein represents a tert-butyl group. The term “OMe” as used herein represents a methoxy group.

[0345] 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 C<sub>6</sub>-C<sub>60</sub> aryl group as a substituent.

[0346] The term “terphenyl group” as used herein refers to “a phenyl group substituted with a biphenyl group. In other words, a terphenyl group is a substituted phenyl group having a C<sub>6</sub>-C<sub>60</sub> aryl group substituted with a C<sub>6</sub>-C<sub>60</sub> aryl group as a substituent.

[0347] \* and \*1 as used herein, unless defined otherwise, each indicate a binding site to an adjacent atom in the corresponding formula.

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

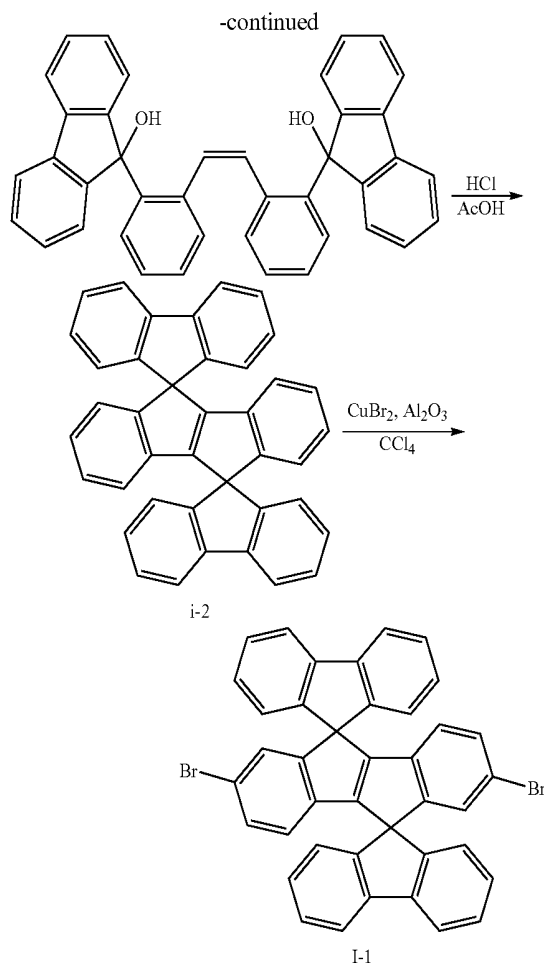
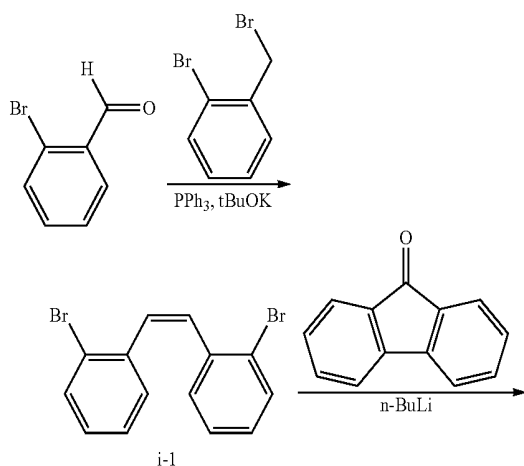
[0349] The following Examples and Comparative Examples are provided in order to highlight characteristics of one or more embodiments, but it will be understood that the Examples and Comparative Examples are not to be construed as limiting the scope of the embodiments, nor are the Comparative Examples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

## EXAMPLE

### Synthesis Example

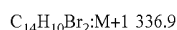
#### Synthesis Example 1: Synthesis of Intermediate I-1

[0350]



[0351] Synthesis of Intermediate i-1

[0352] 74.9 g (300.0 mmol) of 1-bromo-2-(bromomethyl)benzene and 78.6 g (300.0 mmol) of triphenylphosphine were dissolved in 600 ml of tetrahydrofuran (THF) and then stirred at a temperature of 60° C. for 12 hours. The resulting reaction solution was cooled to a temperature of 0° C., and then was slowly added to 40.4 g (360.0 mmol) of KOtBu in 150 mL of THF. About 30 minutes later, 50.0 g (270.0 mmol) of 2-bromobenzaldehyde was slowly added thereto, and the temperature of the reaction solution was slowly raised to ambient temperature, followed by stirring for about 1 hour. An extraction process was performed on the reaction solution three times using diethyl ether and water to collect an organic layer. The collected organic layer was dried over magnesium sulfate (MgSO<sub>4</sub>), and a solvent was next removed therefrom by evaporation. The resulting residue was separated and purified through silica gel column chromatography to obtain 81.3 g of Intermediate Compound i-1 (yield: 89%). The Intermediate Compound i-1 was identified by using liquid chromatography-mass spectrometry (LC-MS) and <sup>1</sup>H nuclear magnetic resonance (NMR).

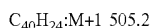


[0353] <sup>1</sup>H NMR (CDCl<sub>3</sub>, 500 MHz) δ 7.58 (dd, 2H), 7.07-6.96 (m, 6H), 6.81 (s, 2H)

[0354] Synthesis of Intermediate i-2

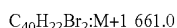
[0355] 8.11 g (24.0 mmol) of Intermediate i-1 was dissolved in 100 mL of diethyl ether, and 33.1 mL (1.6 molar (M) in hexane, 53.0 mmol) of n-BuLi was added thereto at

0° C., followed by stirring at the same temperature for 30 minutes. A solution in which 9.55 g (53.0 mmol) of 9H-fluorene-9-one was dissolved in 20 mL of diethyl ether was added to the solution. Then, the temperature of the reaction solution was slowly raised to ambient temperature, followed by further stirring for 30 minutes. Subsequently, 50 mL of a NaHCO<sub>3</sub> saturated aqueous solution was used to quench the reaction. Thereafter, the reaction solution was filtered. After the filtration, the obtained solid was washed with distilled water and hexane and then dried under vacuum. The resulting dried solid was dissolved in 150 mL of acetic acid, and then 54 μL (12N, 1.5 mmol) of HCl was added thereto, followed by heating under reflux for 2 hours. Next, the reaction solution was cooled to ambient temperature, and then 50 mL of a NaHCO<sub>3</sub> saturated aqueous solution was added to the reaction solution, followed by strong stirring for 30 minutes. The resulting solid was washed with distilled water and methanol and then washed with hexane, followed by drying under vacuum. The solid was recrystallized in CH<sub>2</sub>Cl<sub>2</sub> to obtain 2.78 g of Intermediate Compound i-2 (yield: 23%). Intermediate Compound i-2 was identified by using LC-MS.



#### [0356] Synthesis of Intermediate I-1

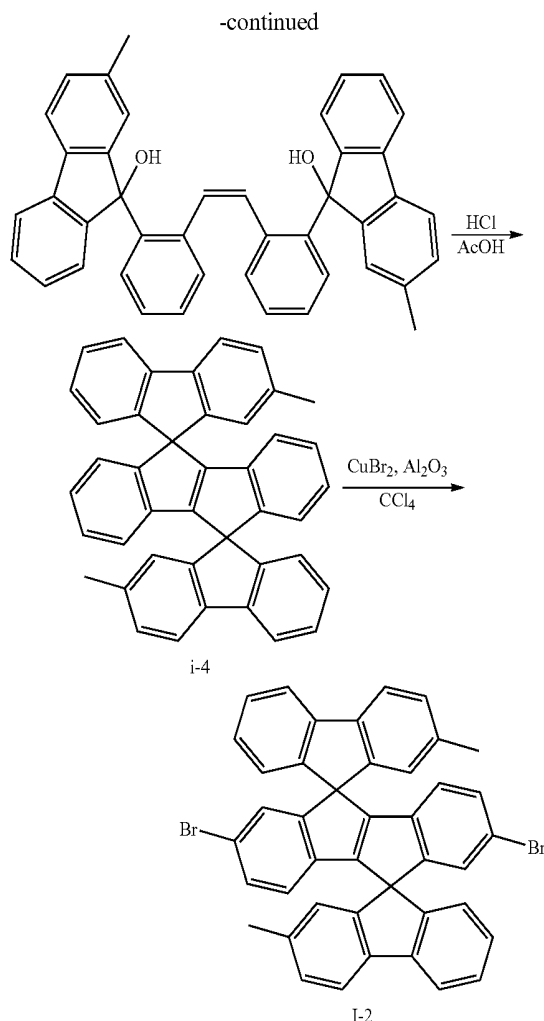
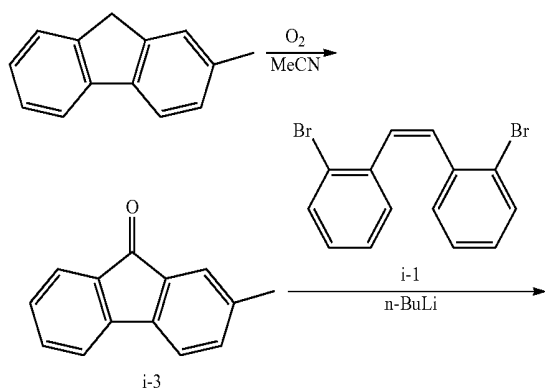
[0357] 2.52 g (5.0 mmol) of Intermediate i-2, 8.37 g (37.5 mmol) of CuBr<sub>2</sub>, and 25.4 g (250.0 mmol) of Al<sub>2</sub>O<sub>3</sub> were incorporated with 50 mL of CCl<sub>4</sub>. Then, the reaction solution was heated under reflux for 24 hours. The reaction solution was cooled to ambient temperature, and the excess CuBr<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub> were filtered using Celite®. The filtrate was vacuum-dried and then separated and purified through silica gel column chromatography to obtain 2.65 g of Intermediate Compound I-1 (yield: 80%). Intermediate Compound I-1 was identified by using LC-MS and <sup>1</sup>H NMR.



[0358] <sup>1</sup>H NMR (CDCl<sub>3</sub>, 500 MHz) δ 7.89 (d, 2H), 7.79 (d, 4H), 7.38-7.33 (m, 6H), 7.18 (d, 2H), 7.08-7.01 (m, 4H), 6.89-6.83 (m, 4H)

#### Synthesis Example 2: Synthesis of Intermediate I-2

#### [0359]



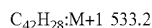
#### [0360] Synthesis of Intermediate i-3

[0361] 12.6 g (70.0 mmol) of 2-methyl-9H-fluorene and 0.79 g (1.05 mmol) of Ru(bpy)<sub>3</sub>Cl<sub>2</sub>·6H<sub>2</sub>O were dissolved in 100 mL of MeCN. Subsequently, a solution in which 0.26 g (0.7 mmol) of Cu(MeCN)<sub>4</sub>OTf was dissolved in 5 mL of MeCN was slowly added thereto with the supply of oxygen from O<sub>2</sub> balloon. The resulting reaction solution was irradiated with white LED light and stirred at ambient temperature for 48 hours. The reaction solution was filtered through a thin silica gel layer using ethyl acetate as a solvent. The filtrate was vacuum-dried and then separated and purified using silica gel column chromatography to obtain 11.1 g of Intermediate Compound i-3 (yield: 82%). Intermediate Compound i-3 was identified by using LC-MS.



#### [0362] Synthesis of Intermediate i-4

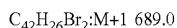
[0363] 2.68 g of Intermediate Compound i-4 was obtained in substantially the same manner as in Synthesis of Intermediate i-2 with the alteration that Intermediate i-3 and Intermediate i-1 were used (yield: 21%). Intermediate Compound i-4 was identified by using LC-MS.



#### [0364] Synthesis of Intermediate I-2

[0365] 2.49 g of Intermediate Compound I-2 was obtained (yield: 72%) in substantially the same manner as in Synthe-

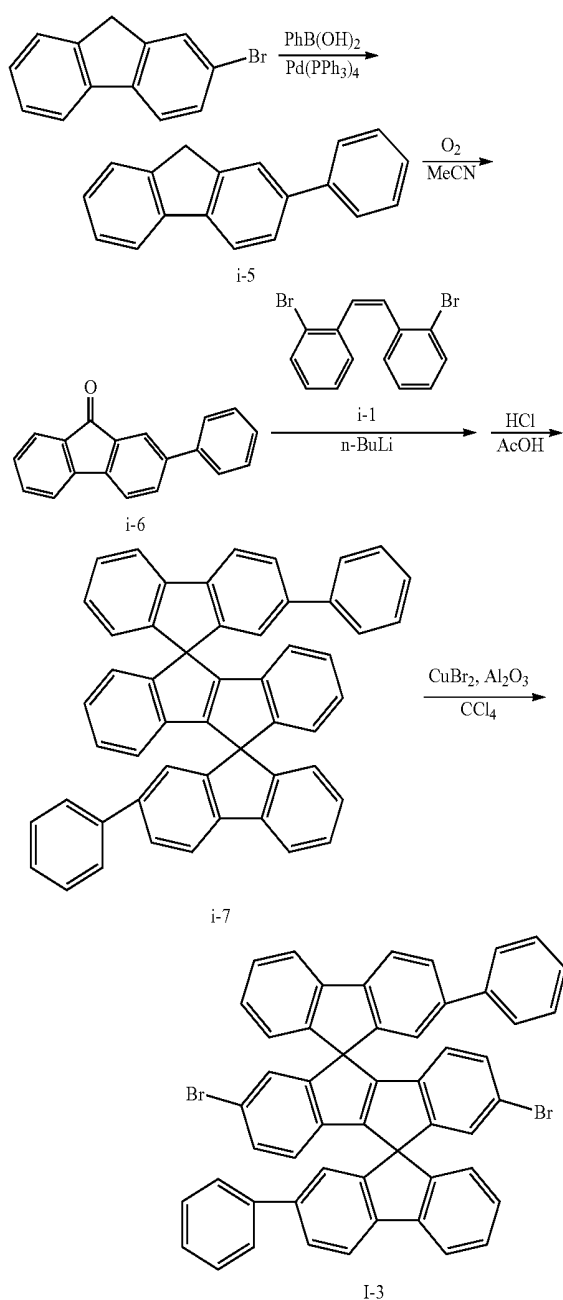
sis of Intermediate I-1, except that Intermediate i-4 was used in place of Intermediate i-2 to synthesize Intermediate I-1. Intermediate Compound I-2 was identified by using LC-MS and  $^1\text{H}$  NMR.



[0366]  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 500 MHz)  $\delta$  7.88 (d, 2H), 7.78-7.69 (m, 4H), 7.40-7.36 (m, 4H), 7.16-7.09 (m, 6H), 6.85-6.82 (m, 4H), 2.41 (s, 6H)

### Synthesis Example 3: Synthesis of Intermediate I-3

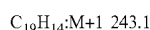
[0367]



[0368] Synthesis of Intermediate i-5

[0369] 24.5 g (100.0 mmol) of 2-bromo-9H-fluorene, 12.2 g (100.0 mmol) of phenylboronic acid, 5.78 g (5.0 mmol) of

$\text{Pd(PPh}_3)_4$ , and 41.4 g (300.0 mmol) of  $\text{K}_2\text{CO}_3$  were dissolved in 300 mL of a mixture solution of THF and  $\text{H}_2\text{O}$ , followed by stirring at a temperature of  $65^\circ\text{C}$ . for 3 hours. The obtained reaction mixture was cooled to ambient temperature, and then an extraction process was performed three times thereon using diethyl ether and water to collect an organic layer. The collected organic layer was dried over  $\text{MgSO}_4$ , and the solvent was next removed therefrom by evaporation. The resulting residue was separated and purified through silica gel column chromatography to obtain 19.8 g of Intermediate Compound i-5 (yield: 82%). Intermediate Compound i-5 was identified by using LC-MS.



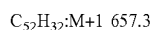
[0370] Synthesis of Intermediate i-6

[0371] 14.2 g of Intermediate Compound i-6 was obtained (yield: 79%) in substantially the same manner as in Synthesis of Intermediate i-3, except that Intermediate Compound i-5 was used in place of 2-methyl-9H-fluorene to synthesize Intermediate i-3. Intermediate Compound i-6 was identified by using LC-MS.



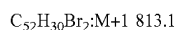
[0372] Synthesis of Intermediate i-7

[0373] 3.78 g of Intermediate Compound i-7 was obtained (yield: 24%) in substantially the same manner as in Synthesis of Intermediate i-2, except that Intermediate Compound i-6 was used in place of 9H-fluorene-9-one to synthesize Intermediate i-2. Intermediate Compound i-7 was identified by using LC-MS.



[0374] Synthesis of Intermediate I-3

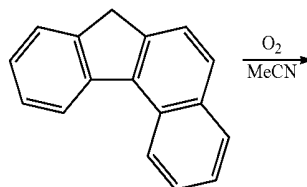
[0375] 3.25 g of Intermediate Compound I-3 was obtained (yield: 80%) in substantially the same manner as in Synthesis of Intermediate I-1, except that Intermediate Compound i-7 was used in place of Intermediate Compound i-2 to synthesize Intermediate I-1. Intermediate Compound I-3 was identified by using LC-MS and  $^1\text{H}$  NMR.

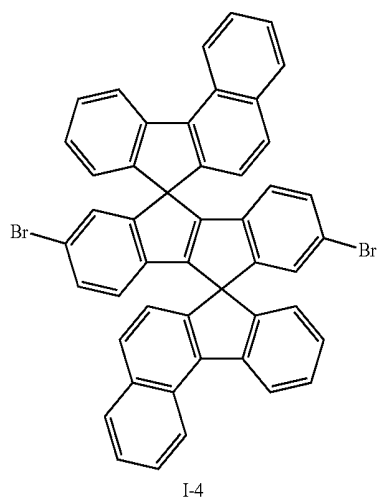
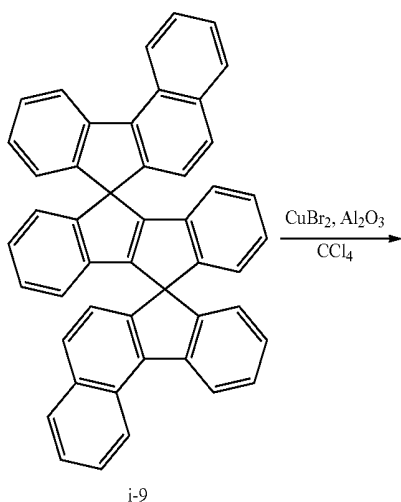
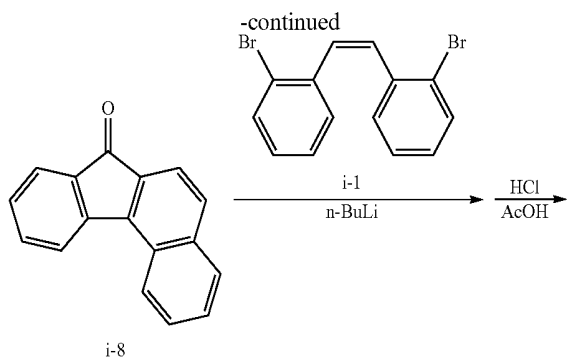


[0376]  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 500 MHz)  $\delta$  7.96 (d, 2H), 7.82 (d, 2H), 7.78-7.68 (m, 6H), 7.54-7.47 (m, 6H), 7.44-7.32 (m, 6H), 7.21-7.18 (m, 4H), 7.08 (dt, 2H), 6.82 (d, 2H)

### Synthesis Example 4: Synthesis of Intermediate I-4

[0377]





**[0378]** Synthesis of Intermediate i-8

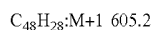
**[0379]** 12.9 g of Intermediate Compound i-8 was obtained (yield: 80%) in substantially the same manner as in Synthesis of Intermediate i-3, except that 7H-benzo[c]fluorene was used in place of 2-methyl-9H-fluorene to synthesize Intermediate i-3. Intermediate Compound i-8 was identified by using LC-MS.



**[0380]** Synthesis of Intermediate i-9

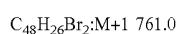
**[0381]** 3.19 g of Intermediate Compound i-9 was obtained (yield: 22%) in substantially the same manner as in Synthesis

of Intermediate i-2, except that Intermediate Compound i-8 was used in place of 9H-fluorene-9-one to synthesize Intermediate i-2. Intermediate Compound i-9 was identified by using LC-MS.



**[0382]** Synthesis of Intermediate I-4

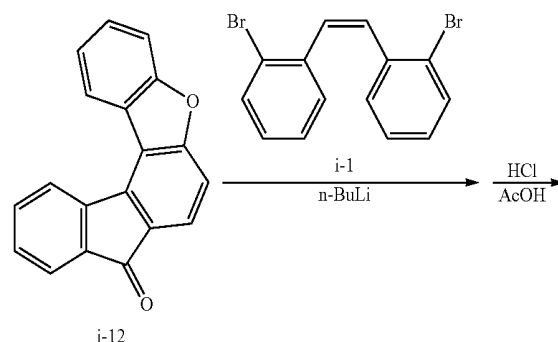
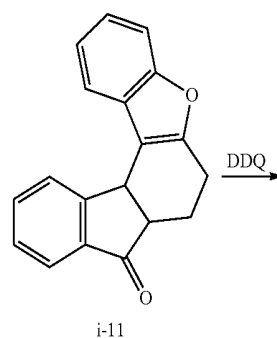
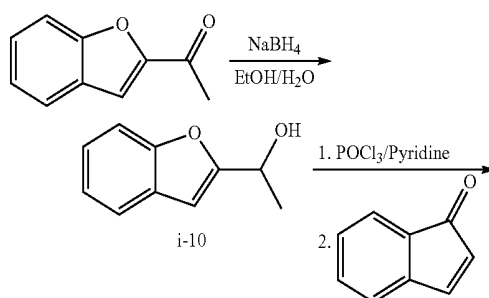
**[0383]** 2.89 g of Intermediate Compound 1-4 was obtained (yield: 76%) in substantially the same manner as in Synthesis of Intermediate I-1, except that Intermediate Compound i-9 was used in place of Intermediate Compound i-2 to synthesize Intermediate I-1. Intermediate Compound 1-4 was identified by using LC-MS and <sup>1</sup>H NMR.

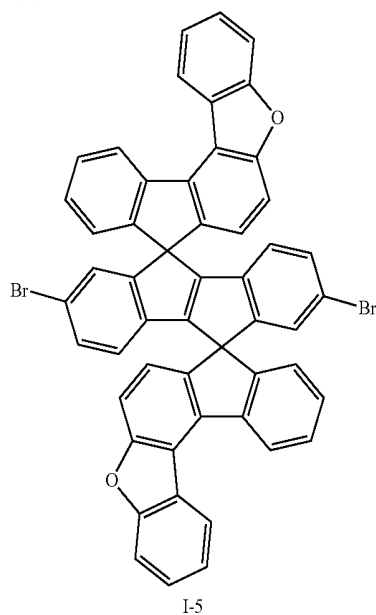
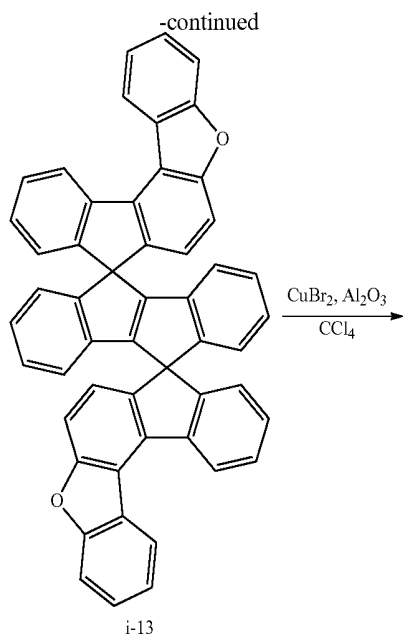


**[0384]** <sup>1</sup>H NMR (CDCl<sub>3</sub>, 500 MHz) δ 7.97 (d, 2H), 7.92 (d, 2H), 7.75 (d, 2H), 7.59-7.49 (m, 2H), 7.48-7.27 (m, 8H), 7.15 (d, 2H), 7.12-7.03 (m, 4H), 6.95 (d, 2H), 6.83-6.79 (m, 2H)

Synthesis Example 5: Synthesis of Intermediate I-5

**[0385]**



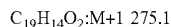
**[0386]** Synthesis of Intermediate i-10

**[0387]** 32.0 g (200.0 mmol) of 1-(benzo[b]furan-2-yl) ethanone was dissolved in 500 mL of ethanol. The obtained reaction solution was heated under reflux, and then a solution in which 75.6 g (2.0 mol) of  $\text{NaBH}_4$  was dissolved in 100 mL of water was added to the reaction solution, followed by heating under reflux for 5 hours. The resulting reaction solution was cooled to ambient temperature, and then an organic layer extracted using  $\text{CHCl}_3$  was dried over  $\text{Na}_2\text{SO}_4$ . Subsequently, the solvent was removed therefrom by evaporation. The obtained residue was separated and purified using silica gel column chromatography to obtain 27.6 g of Intermediate Compound i-10 (yield: 85%). Intermediate Compound i-10 was identified by using LC-MS.

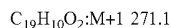
**[0388]** Synthesis of Intermediate i-11

**[0389]** A solution in which 28.0 mL (300.0 mmol) of  $\text{POCl}_3$  was dissolved in 30 mL of pyridine was added to a

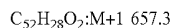
solution in which 24.3 g (150.0 mmol) of Intermediate i-10 was dissolved in 400 mL of toluene, followed by heating under reflux for 20 hours. After the starting material, alcohol, was removed from the obtained reaction solution, 20.8 g (160.0 mmol) of 3-bromoindan-1-one was added to the reaction solution, followed by heating under reflux for 48 hours. While reflux, 20.8 g of 3-bromoindan-1-one was further added two times thereto. The reaction solution was cooled to ambient temperature, a cold 5% sulfuric acid aqueous solution was added thereto, an extraction process was performed thereon using  $\text{CHCl}_3$ , and a further extraction process was performed two times thereon using saturated  $\text{NaHCO}_3$  aqueous solution. The resulting organic layer was dried over  $\text{Na}_2\text{SO}_4$ , and the solvent was removed therefrom by evaporation. The resulting residue was separated and purified through silica gel column chromatography to obtain 25.5 g of Intermediate Compound i-11 (yield: 62%). Intermediate Compound i-11 was identified by using LC-MS.

**[0390]** Synthesis of Intermediate i-12

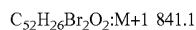
**[0391]** 45.4 g (200.0 mmol) of 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (DDQ) was added to a solution in which 24.6 g (90.0 mol) of Intermediate i-11 was dissolved in 200 mL of benzene, followed by heating under reflux at a temperature of 90° C. for 10 hours. The obtained reaction solution was cooled to ambient temperature and then diluted with 100 mL of benzene. Subsequently, an extraction process was performed thereon using a 10%  $\text{Na}_2\text{S}_2\text{O}_4$  aqueous solution and a 10% KOH aqueous solution. Then an organic layer was dried over  $\text{Na}_2\text{SO}_4$ , and the solvent was removed therefrom by evaporation. The resulting residue was separated and purified through silica gel column chromatography to obtain 19.5 g of Intermediate Compound i-12 (yield: 80%). Intermediate Compound i-12 was identified by using LC-MS.

**[0392]** Synthesis of Intermediate i-13

**[0393]** 3.12 g of Intermediate Compound i-13 was obtained (yield: 19%) in substantially the same manner as in Synthesis of Intermediate i-2, except that Intermediate Compound i-12 was used in place of 9H-fluorene-9-one to synthesize Intermediate i-2. Intermediate Compound i-13 was identified by using LC-MS.

**[0394]** Synthesis of Intermediate I-5

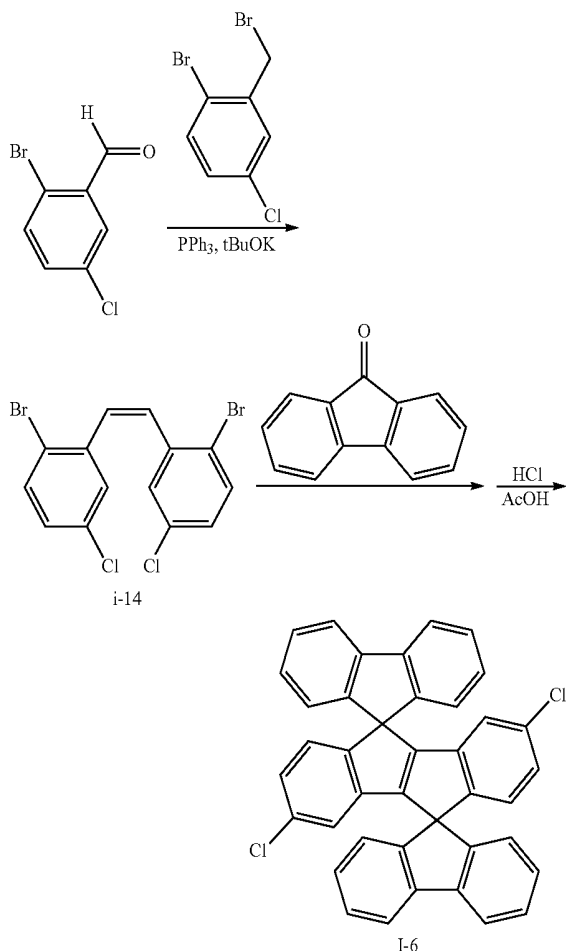
**[0395]** 2.78 g of Intermediate Compound I-5 was obtained (yield: 66%) in substantially the same manner as in Synthesis of Intermediate I-1, except that Intermediate Compound i-13 was used in place of Intermediate Compound i-2 to synthesize Intermediate I-1. Intermediate Compound I-5 was identified by using LC-MS and  $^1\text{H}$  NMR.



**[0396]**  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 500 MHz)  $\delta$  7.94 (–7.89 (m, 4H), 7.88 (d, 2H), 7.69 (d, 2H), 7.54–7.36 (m, 10H), 7.20–7.14 (m, 4H), 7.03–6.97 (m, 2H), 6.87–6.82 (m, 2H)

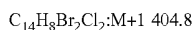
## Synthesis Example 6: Synthesis of Intermediate I-6

[0397]



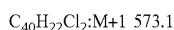
[0398] Synthesis of Intermediate i-14

[0399] 21.5 g of Intermediate Compound i-14 was obtained (yield: 53%) in substantially the same manner as in Synthesis of Intermediate i-1, except that 28.4 g (100.0 mmol) of 1-bromo-2-(bromomethyl)-4-chlorobenzene was used in place of 1-bromo-2-(bromomethyl)benzene, and 21.9 g (100.0 mmol) of 2-bromo-5-chlorobenzaldehyde was used instead of 2-bromobenzaldehyde to synthesize Intermediate i-1. Intermediate Compound i-14 was identified by using LC-MS.



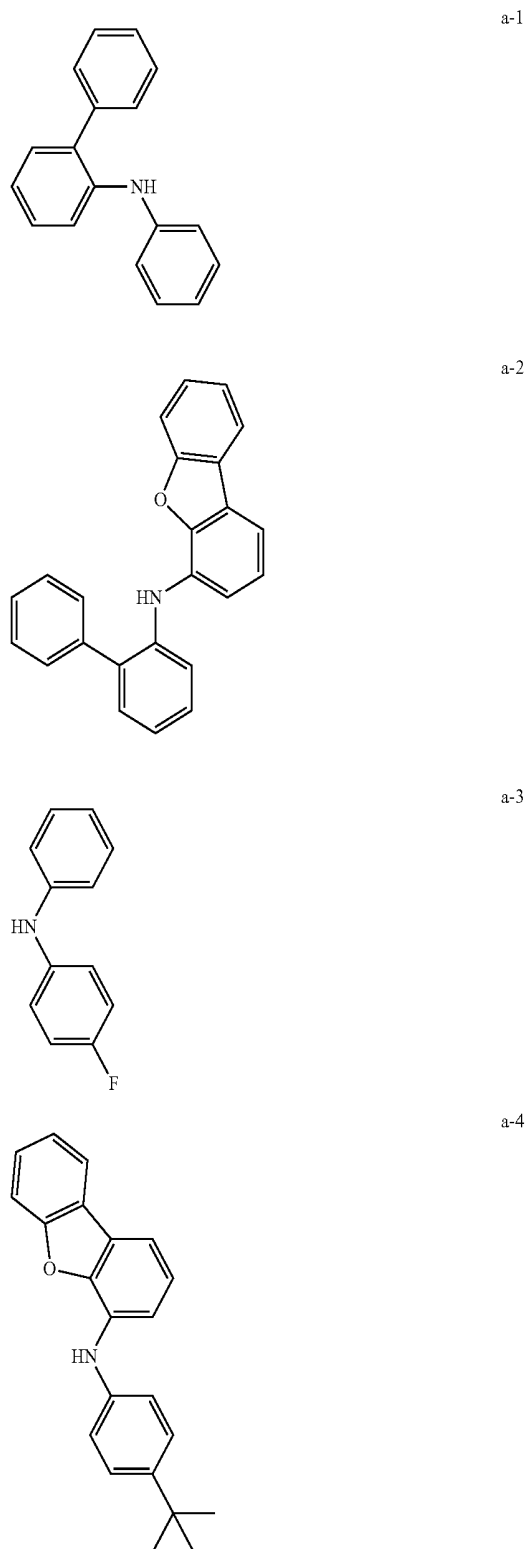
[0400] Synthesis of Intermediate I-6

[0401] 4.87 g of Intermediate Compound I-6 was obtained (yield: 17%) in substantially the same manner as in Synthesis of Intermediate I-2, except that 20.3 g (50.0 mmol) of Intermediate i-14 was used in place of Intermediate i-1, and 19.8 g (110.0 mmol) of 9H-fluorene-9-one was used to synthesize Intermediate I-2. Intermediate Compound I-6 was identified by using LC-MS and <sup>1</sup>H NMR.

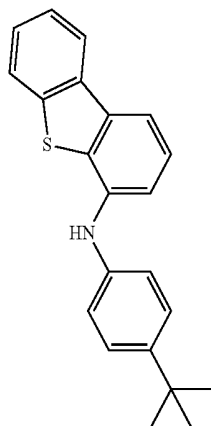
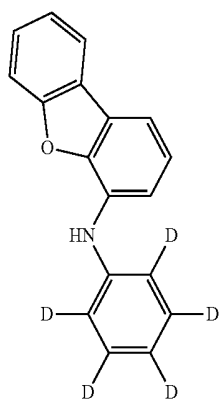
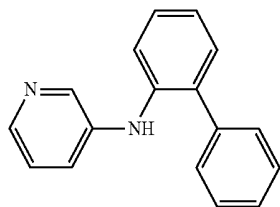
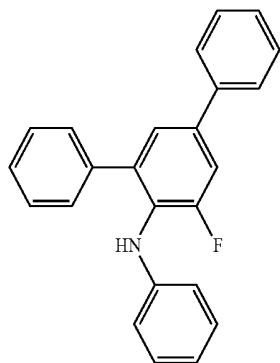


[0402] <sup>1</sup>H NMR (CDCl<sub>3</sub>, 500 MHz) δ 8.04 (d, 2H), 7.80 (d, 4H), 7.37 (dt, 4H), 7.19 (d, 2H), 7.12 (dt, 4H), 7.02 (d, 2H), 6.93-6.88 (m, 4H)

[0403] Synthesized compounds according to one or more embodiments may be readily synthesized using the synthesized Intermediate Compounds I-1 to I-6 and secondary amine compounds (a-1 to a-11). The following is a representative synthesizing method.

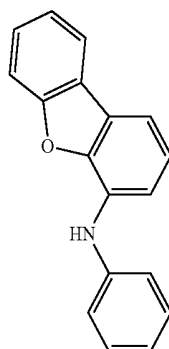


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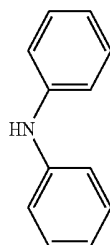
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a-5



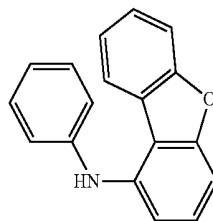
a-9

a-6



a-10

a-7

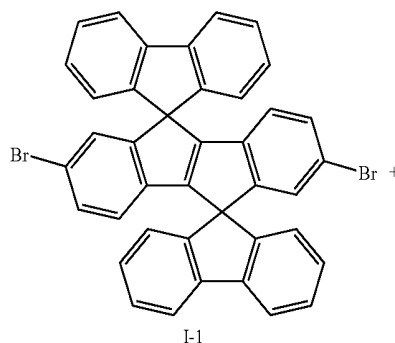


a-11

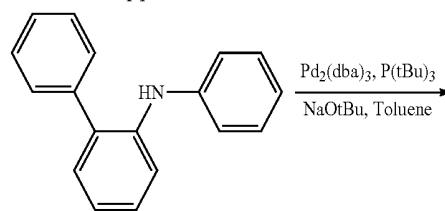
Synthesis Example 7: Synthesis of Compounds 1 to 64

[0404]

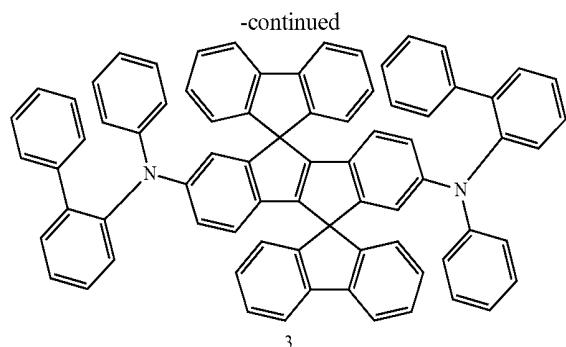
a-8



I-1



a-1



**[0405]** Synthesis of Compound 3

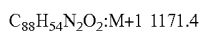
**[0406]** 1.98 g (3.0 mmol) of Intermediate I-1, 1.62 g (6.6 mmol) of amine compound a-1, 0.14 g (0.15 mmol) of  $\text{Pd}_2(\text{dba})_3$ , 0.03 g (0.15 mmol) of  $\text{P}(\text{tBu})_3$ , and 0.86 g (9.0 mol) of  $\text{NaOtBu}$  were dissolved in 20 mL of toluene, and then the mixture was stirred at a temperature of about 80° C. for 5 hours. The obtained reaction solution was cooled to ambient temperature, and 20 mL of water was added thereto, followed by an extraction process performed thereon three times using 20 mL of diethyl ether. The collected organic layer was dried over  $\text{MgSO}_4$ . The solvent was removed therefrom by evaporation. The resulting residue was separated and purified through silica gel chromatography to obtain 2.52 g of Compound 3 (yield: 85%). Compound 3 was identified by using LC-MS and  $^1\text{H}$  NMR.



**[0407]**  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 500 MHz)  $\delta$  7.81 (d, 4H), 7.59-7.48 (m, 10H), 7.38 (dt, 4H), 7.31-7.25 (m, 4H), 7.19-7.01 (m, 14H), 6.95-6.91 (m, 2H), 6.93-6.89 (m, 6H), 6.82 (d, 2H), 6.79-6.74 (m, 4H)

**[0408]** Synthesis of Compound 5

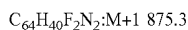
**[0409]** 2.92 g of Compound 5 was obtained (yield: 83%) in substantially the same manner as in Synthesis of Compound 3, except that Compound a-2 was used in place of Compound a-1 to synthesize Compound 3. Compound 5 was identified by using LC-MS and  $^1\text{H}$  NMR.



**[0410]**  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 500 MHz)  $\delta$  7.84-7.79 (m, 6H), 7.73-7.69 (m, 2H), 7.63-7.45 (m, 16H), 7.40 (dt, 4H), 7.34-7.27 (m, 4H), 7.19-7.07 (m, 14H), 6.96-6.87 (m, 6H), 6.87 (d, 2H)

**[0411]** Synthesis of Compound 9

**[0412]** 1.97 g of Compound 9 was obtained (yield: 75%) in substantially the same manner as in Synthesis of Compound 3, except that Compound a-3 was used in place of Compound a-1 to synthesize Compound 3. Compound 9 was identified by using LC-MS and  $^1\text{H}$  NMR.

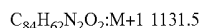


**[0413]**  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 500 MHz)  $\delta$  7.83 (d, 4H), 7.41 (dt, 4H), 7.34-7.17 (m, 18H), 7.03-6.97 (m, 2H), 6.93-6.87 (m, 8H), 6.83-6.78 (m, 4H)

**[0414]** Synthesis of Compound 15

**[0415]** 2.64 g of Compound 15 was obtained (yield: 78%) in substantially the same manner as in Synthesis of Com-

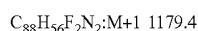
ound 3, except that Compound a-4 was used in place of Compound a-1 to synthesize Compound 3. Compound 15 was identified by using LC-MS and  $^1\text{H}$  NMR.



**[0416]**  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 500 MHz)  $\delta$  7.86-7.79 (m, 6H), 7.74-7.39 (m, 2H), 7.61-7.39 (m, 14H), 7.33 (d, 2H), 7.27-7.15 (m, 12H), 7.04-6.98 (m, 8H), 1.48 (s, 18H)

**[0417]** Synthesis of Compound 19

**[0418]** 2.54 g of Compound 19 was obtained (yield: 72%) in substantially the same manner as in Synthesis of Compound 3, except that Compound a-5 was used in place of Compound a-1 to synthesize Compound 3. Compound 19 was identified by using LC-MS and  $^1\text{H}$  NMR.



**[0419]**  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 500 MHz)  $\delta$  7.84 (d, 4H), 7.74-7.60 (m, 10H), 7.58-7.43 (m, 16H), 7.32-7.16 (m, 10H), 7.11 (d, 2H), 7.03-6.87 (m, 10H), 6.83-6.78 (m, 4H)

**[0420]** Synthesis of Compound 21

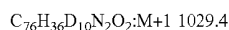
**[0421]** 1.91 g of Compound 21 was obtained (yield: 64%) in substantially the same manner as in Synthesis of Compound 3, except that Compound a-6 was used in place of Compound a-1 to synthesize Compound 3. Compound 21 was identified by using LC-MS and  $^1\text{H}$  NMR.



**[0422]**  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 500 MHz)  $\delta$  8.53 (d, 2H), 8.05 (d, 2H), 7.84 (d, 4H), 7.63-7.54 (m, 10H), 7.43-7.29 (m, 10H), 7.19-7.04 (12H), 6.93 (d, 2H), 6.87-6.81 (m, 6H)

**[0423]** Synthesis of Compound 33

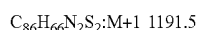
**[0424]** 2.44 g of Compound 33 was obtained (yield: 79%) in substantially the same manner as in Synthesis of Compound 3, except that Compound a-7 was used in place of Compound a-1 to synthesize Compound 3. Compound 33 was identified by using LC-MS and  $^1\text{H}$  NMR.



**[0425]**  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 500 MHz)  $\delta$  7.86-7.79 (m, 6H), 7.72-7.69 (m, 2H), 7.59-7.42 (m, 6H), 7.39 (dt, 4H), 7.34 (d, 2H), 7.26-7.09 (m, 12H), 6.94-6.89 (m, 4H)

**[0426]** Synthesis of Compound 44

**[0427]** 2.71 g of Compound 44 was obtained (yield: 76%) in substantially the same manner as in Synthesis of Compound 3, except that Intermediate Compound I-2 was used instead of Intermediate Compound I-1, and Compound a-8 was used in place of Compound a-1 to synthesize Compound 3. Compound 44 was identified using LC-MS and  $^1\text{H}$  NMR.

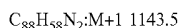


**[0428]**  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 500 MHz)  $\delta$  8.06 (d, 2H), 7.96 (d, 2H), 7.84-7.72 (m, 6H), 7.64 (dt, 2H), 7.50-7.33 (m, 10H), 7.23-7.07 (m, 8H), 6.99-6.92 (m, 6H), 6.86-6.79 (m, 6H), 2.41 (s, 6H), 1.48 (s, 18H)

**[0429]** Synthesis of Compound 45

**[0430]** 2.71 g of Compound 45 was obtained (yield: 79%) in substantially the same manner as in Synthesis of Compound 1-3, except that Intermediate Compound I-3 was used

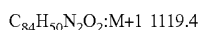
in place of Intermediate Compound I-3 to synthesize Compound 3. Compound 45 was identified by using LC-MS and  $^1\text{H}$  NMR.



**[0431]**  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 500 MHz)  $\delta$  7.82 (d, 2H), 7.78-7.68 (m, 6H), 7.64-7.43 (m, 20H), 7.34-7.16 (m, 16H), 7.12 (d, 2H), 7.03-6.94 (m, 6H), 6.89-6.82 (m, 6H)

**[0432]** Synthesis of Compound 49

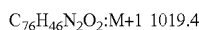
**[0433]** 2.68 g of Compound 49 was obtained (yield: 80%) in substantially the same manner as in Synthesis of Compound 3, except that Intermediate Compound I-4 was used instead of Intermediate Compound I-1, and Compound a-9 was used in place of Compound a-1 to synthesize Compound 3. Compound 49 was identified by using LC-MS and  $^1\text{H}$  NMR.



**[0434]**  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 500 MHz)  $\delta$  7.93 (d, 2H), 7.84-7.74 (m, 8H), 7.66-7.32 (m, 14H), 7.26-7.08 (m, 18H), 7.02-6.97 (m, 2H), 6.84-6.77 (m, 61-1)

**[0435]** Synthesis of Compound 51

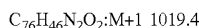
**[0436]** 2.38 g of Compound 51 was obtained (yield: 78%) in substantially the same manner as in Synthesis of Compound 3, except that Intermediate Compound I-5 was used instead of Intermediate Compound I-1, and Compound a-10 was used in place of Compound a-1 to synthesize Compound 3. Compound 51 was identified by using LC-MS and  $^1\text{H}$  NMR.



**[0437]**  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 500 MHz)  $\delta$  7.97 (d, 2H), 7.91 (d, 2H), 7.71-7.51 (m, 10H), 7.31 (d, 2H), 7.19-7.11 (m, 10H), 7.04-6.93 (m, 8H), 6.86-6.78 (m, 12H)

**[0438]** Synthesis of Compound 64

**[0439]** 1.92 g of Compound 64 was obtained (yield: 63%) in substantially the same manner as in Synthesis of Compound 3, except that Intermediate Compound I-6 was used instead of Intermediate Compound I-1, and Compound a-11 was used in place of Compound a-1 to synthesize Compound 3. Compound 64 was identified by using LC-MS and  $^1\text{H}$  NMR.



**[0440]**  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 500 MHz)  $\delta$  7.82-7.70 (m, 8H), 7.52-7.38 (m, 12H), 7.21-7.08 (m, 10H), 6.99-6.91 (m, 4H), 6.88-6.81 (m, 10H), 6.78 (d, 2H)

#### Example 1

**[0441]** A substrate, on which ITO, Ag, and ITO were deposited at a thickness of about 70 Å, 1,000 Å, and 70 Å, respectively, was cut to a size of 50 millimeters (mm)×50 mm×0.5 mm, sonicated in isopropyl alcohol and pure water for 5 minutes in each solvent, and cleaned by exposure to ultraviolet rays for 30 minutes and then exposed to ozone to use the glass substrate as an anode. Then, the glass substrate was mounted on a vacuum-deposition device.

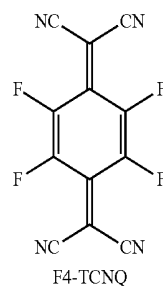
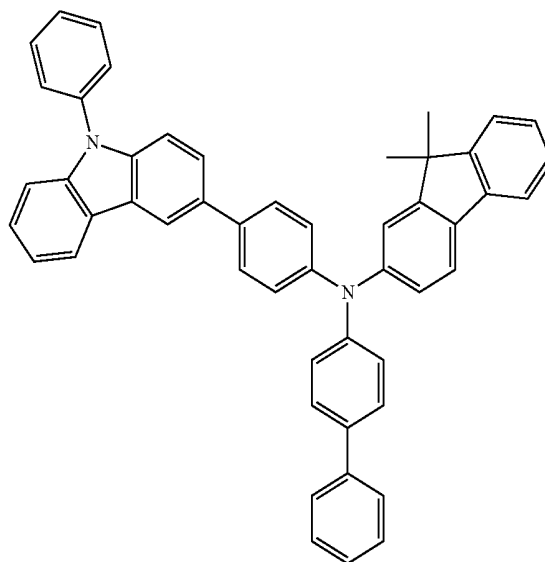
**[0442]** N-([1,1'-biphenyl]-4-yl)-9,9-dimethyl-N-(4-(9-phenyl-9H-carbazol-3-yl)phenyl)-9H-fluoren-2-amine (Compound 301) and F4-TCNQ were co-vacuum-deposited

at a weight ratio of 98:2 on the ITO anode on the glass substrate to form a hole injection layer having a thickness of 100 Å. Subsequently, Compound 301 was vacuum-deposited as a hole transport compound on the hole injection layer to form a first hole transport layer having a thickness of 1,200 Å, and N,N-di([1,1'-biphenyl]-4-yl)-4'-(9H-carbazol-9-yl)-[1,1'-biphenyl]-4-amine (Compound A), was vacuum-deposited on the first hole transport layer to form a second hole transport layer having a thickness of 100 Å.

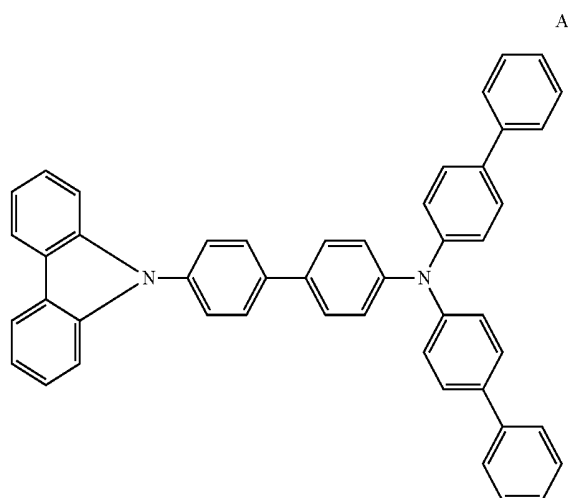
**[0443]** 9,10-di-naphthalene-2-yl-anthracene (ADN, as a blue fluorescent host) and Compound 3 as a blue fluorescent dopant were co-deposited at a weight ratio of 98:2 on the second hole transport layer to form an emission layer having a thickness of 300 Å.

**[0444]** Subsequently, 2-(4-(9,10-di(naphthalene-2-yl)anthracen-2-yl)phenyl)-1-phenyl-1H-benzo[d]imidazole (Compound B, as an electron transport compound) and LiQ were co-deposited at a weight ratio of 5:5 on the emission layer to form an electron transport layer having a thickness of 300 Å. A halogenated alkali metal LiF was deposited on the electron transport layer at a thickness of 10 Å to form an electron injection layer, and then MgAg was vacuum-deposited at a weight ratio of 90:10 on the electron injection layer to form a cathode having a thickness of 120 Å, thereby completing the manufacture of an organic light-emitting device.

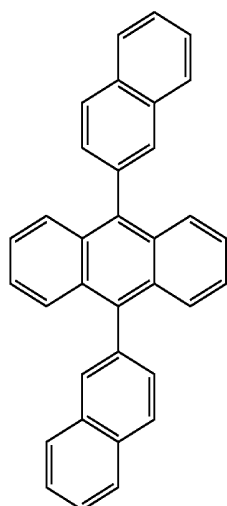
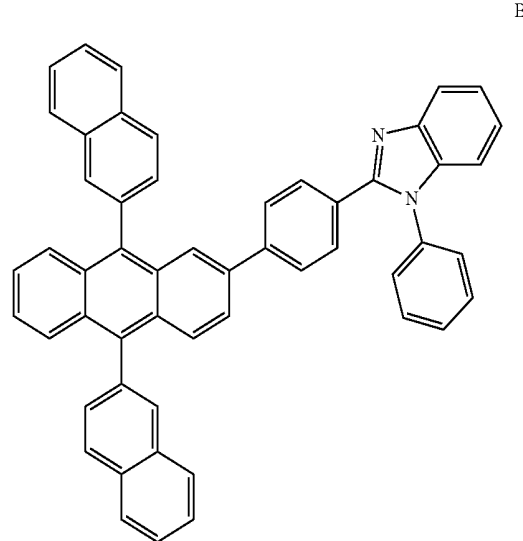
301



-continued



-continued



ADN

Examples 2 to 12 and Comparative Examples 1 to 3

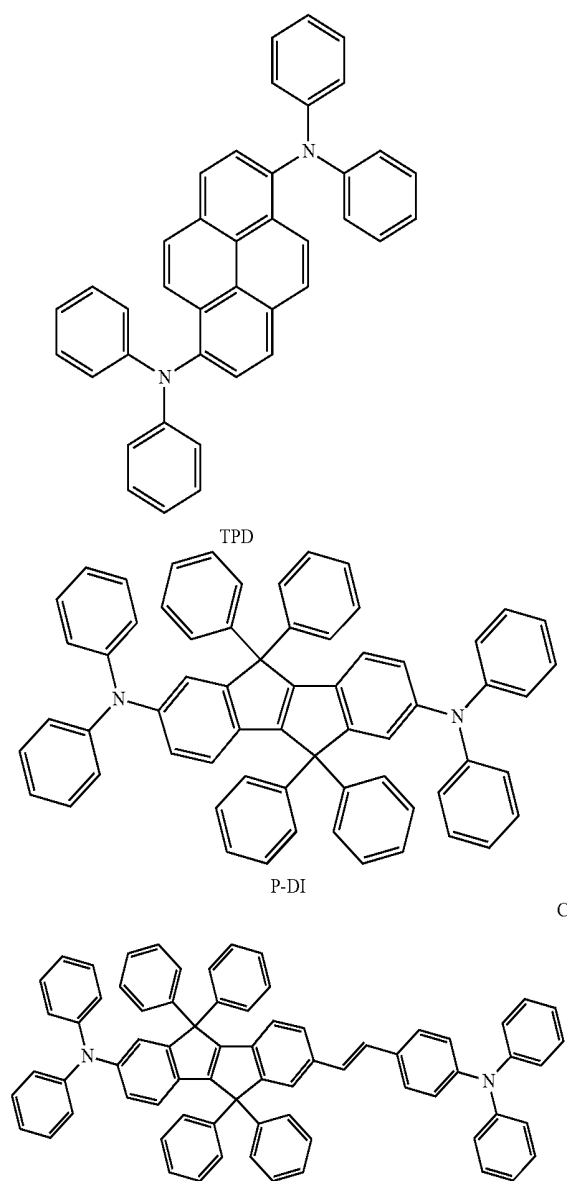
[0445] Organic light-emitting devices were manufactured in substantially the same manner as in Example 1, except that the compounds shown in Table 2 were used instead of Compound 3 as a dopant in forming each emission layer.

#### Evaluation Example 1

[0446] The driving voltage, luminance, efficiency, and color-coordinate of the organic light-emitting devices manufactured in Examples 1 to 12 and Comparative Examples 1 to 3 at a current density of 10 mA/cm<sup>2</sup> were measured. T97 lifespan was also measured at a current density of 1.0 mA/cm<sup>2</sup>, which indicates time (hour) for the luminance of each organic light-emitting device to decline to 97% of its initial luminance. The evaluation results are shown in Table 1.

TABLE 1

	Dopant	Driving voltage (V)	Current density (mA/cm <sup>2</sup> )	Efficiency (cd/A)	Color-coordinate CIE(x, y)	T97 lifespan (@1.0 mA/cm <sup>2</sup> )
Example 1	Compound 3	4.5	10	4.97	0.140, 0.051	143
Example 2	Compound 5	4.5	10	5.22	0.141, 0.052	168
Example 3	Compound 9	4.5	10	5.01	0.141, 0.050	153
Example 4	Compound 15	4.5	10	5.16	0.140, 0.052	163
Example 5	Compound 19	4.5	10	5.13	0.141, 0.052	165
Example 6	Compound 21	4.5	10	4.96	0.141, 0.052	98
Example 7	Compound 33	4.5	10	5.15	0.142, 0.051	141
Example 8	Compound 44	4.5	10	4.98	0.140, 0.053	125
Example 9	Compound 45	4.5	10	5.19	0.141, 0.052	169
Example 10	Compound 49	4.5	10	5.21	0.141, 0.054	141
Example 11	Compound 51	4.5	10	5.26	0.141, 0.052	177
Example 12	Compound 64	4.5	10	4.89	0.141, 0.052	102
Comparative Example 1	TPD	4.5	10	4.65	0.141, 0.051	70
Comparative Example 2	P-DI	4.5	10	4.55	0.141, 0.054	65
Comparative Example 3	C	4.5	10	4.37	0.143, 0.059	42



[0447] As may be seen in Table 1, the organic light-emitting devices of Examples 1 to 12 were found to have high luminance, high efficiency, and long lifespan, as compared with the organic light-emitting devices of Comparative Examples 1 to 3.

[0448] As apparent from the foregoing description, an organic light-emitting device including the condensed-cyclic compound may have high luminance, high efficiency, and long lifespan.

[0449] The embodiments may provide an organic light-emitting device with high luminance, high efficiency, and long lifespan characteristics.

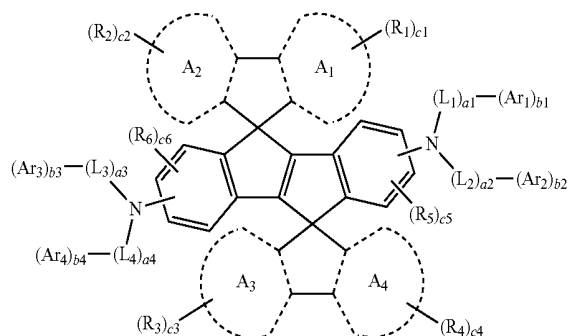
[0450] Example embodiments have been disclosed herein, and although specific terms are employed, they are used and are to be interpreted in a generic and descriptive sense only and not for purpose of limitation. In some instances, as would be apparent to one of ordinary skill in the art as of the filing of the present application, features, characteristics, and/or elements described in connection with a particular

embodiment may be used singly or in combination with features, characteristics, and/or elements described in connection with other embodiments unless otherwise specifically indicated. Accordingly, it will be understood by those of skill in the art that various changes in form and details may be made without departing from the spirit and scope of the present invention as set forth in the following claims.

What is claimed is:

1. A condensed-cyclic compound represented by Formula 1:

Formula 1



wherein, in Formula 1,

A<sub>1</sub> to A<sub>4</sub> are each independently selected from a C<sub>6</sub>-C<sub>60</sub> carbocyclic group and a C<sub>2</sub>-C<sub>60</sub> heterocyclic group,

L<sub>1</sub> to L<sub>4</sub> are each independently selected from a substituted or unsubstituted C<sub>3</sub>-C<sub>10</sub> cycloalkylene group, a substituted or unsubstituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkylene group, a substituted or unsubstituted C<sub>3</sub>-C<sub>10</sub> cycloalkenylene group, a substituted or unsubstituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkenylene group, a substituted or unsubstituted C<sub>6</sub>-C<sub>60</sub> arylene group, a substituted or unsubstituted C<sub>1</sub>-C<sub>60</sub> heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

a<sub>1</sub> to a<sub>4</sub> are each independently an integer of 0 to 3; when a<sub>1</sub> is 2 or greater, L<sub>1</sub>(s) are identical to or different from each other, when a<sub>2</sub> is 2 or greater, L<sub>2</sub>(s) are identical to or different from each other, when a<sub>3</sub> is 2 or greater, L<sub>3</sub>(s) are identical to or different from each other, when a<sub>4</sub> is 2 or greater, L<sub>4</sub>(s) are identical to or different from each other,

Ar<sub>1</sub> to Ar<sub>4</sub> are each independently selected from a substituted or unsubstituted C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a substituted or unsubstituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a substituted or unsubstituted C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a substituted or unsubstituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a substituted or unsubstituted C<sub>6</sub>-C<sub>60</sub> aryl group, a substituted or unsubstituted C<sub>6</sub>-C<sub>60</sub> aryloxy group, a substituted or unsubstituted C<sub>6</sub>-C<sub>60</sub> arylthio group, a substituted or unsubstituted C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group,

b<sub>1</sub> to b<sub>4</sub> are each independently an integer of 1 to 5; when b<sub>1</sub> is 2 or greater, Ar<sub>1</sub>(s) are identical to or different

from each other, when b2 is 2 or greater, Ar<sub>2</sub>(s) are identical to or different from each other, when b3 is 2 or greater, Ar<sub>3</sub>(s) are identical to or different from each other, when b4 is 2 or greater, Ar<sub>4</sub>(s) are identical to or different from each other,

R<sub>1</sub> to R<sub>6</sub> are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxy group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C<sub>1</sub>-C<sub>60</sub> alkyl group, a substituted or unsubstituted C<sub>2</sub>-C<sub>60</sub> alkenyl group, a substituted or unsubstituted C<sub>2</sub>-C<sub>60</sub> alkynyl group, a substituted or unsubstituted C<sub>1</sub>-C<sub>60</sub> alkoxy group, a substituted or unsubstituted C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a substituted or unsubstituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a substituted or unsubstituted C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a substituted or unsubstituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a substituted or unsubstituted C<sub>6</sub>-C<sub>60</sub> aryl group, a substituted or unsubstituted C<sub>6</sub>-C<sub>60</sub> aryloxy group, a substituted or unsubstituted C<sub>6</sub>-C<sub>60</sub> arylthio group, a substituted or unsubstituted C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, and —Si(Q<sub>1</sub>)(Q<sub>2</sub>)(Q<sub>3</sub>),

c1 and c4 are each independently an integer of 0 to 6; when c1 is 2 or greater, R<sub>1</sub>(s) are identical to or different from each other, when c2 is 2 or greater, R<sub>2</sub>(s) are identical to or different from each other, when c3 is 2 or greater, R<sub>3</sub>(s) are identical to or different from each other, when c4 is 2 or greater, R<sub>4</sub>(s) are identical to or different from each other,

c5 and c6 are each independently an integer of 0 to 3; when c5 is 2 or greater, R<sub>5</sub>(s) are identical to or different from each other, when c6 is 2 or greater, R<sub>6</sub>(s) are identical to or different from each other, and

at least one substituent of the substituted C<sub>3</sub>-C<sub>10</sub> cycloalkylene group, substituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkylene group, substituted C<sub>3</sub>-C<sub>10</sub> cycloalkenylene group, substituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkenylene group, substituted C<sub>6</sub>-C<sub>60</sub> arylene group, substituted C<sub>1</sub>-C<sub>60</sub> heteroarylene group, substituted divalent non-aromatic condensed polycyclic group, substituted divalent non-aromatic condensed heteropolycyclic group, substituted C<sub>1</sub>-C<sub>60</sub> alkyl group, substituted C<sub>2</sub>-C<sub>60</sub> alkenyl group, substituted C<sub>2</sub>-C<sub>60</sub> alkynyl group, substituted C<sub>1</sub>-C<sub>60</sub> alkoxy group, substituted C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, substituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, substituted C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, substituted C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, substituted C<sub>6</sub>-C<sub>60</sub> aryl group, substituted C<sub>6</sub>-C<sub>60</sub> aryloxy group, substituted C<sub>6</sub>-C<sub>60</sub> arylthio group, substituted C<sub>1</sub>-C<sub>60</sub> heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic condensed heteropolycyclic group is selected from:

deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C<sub>1</sub>-C<sub>60</sub> alkyl group, a C<sub>2</sub>-C<sub>60</sub> alkenyl group, a C<sub>2</sub>-C<sub>60</sub> alkynyl group, and a C<sub>1</sub>-C<sub>60</sub> alkoxy group;

a C<sub>1</sub>-C<sub>60</sub> alkyl group, a C<sub>2</sub>-C<sub>60</sub> alkenyl group, a C<sub>2</sub>-C<sub>60</sub> alkynyl group, and a C<sub>1</sub>-C<sub>60</sub> alkoxy group, each substituted with at least one selected from deuterium, —F,

—Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>6</sub>-C<sub>60</sub> aryloxy group, a C<sub>6</sub>-C<sub>60</sub> arylthio group, a C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —Si(Q<sub>11</sub>)(Q<sub>12</sub>)(Q<sub>13</sub>), —N(Q<sub>11</sub>)(Q<sub>12</sub>), —B(Q<sub>11</sub>)(Q<sub>12</sub>), —C(=O)(Q<sub>1</sub>), —S(=O)<sub>2</sub>(Q<sub>11</sub>), and —P(=O)(Q<sub>11</sub>)(Q<sub>12</sub>);

a C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>6</sub>-C<sub>60</sub> aryloxy group, a C<sub>6</sub>-C<sub>60</sub> arylthio group, a C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

a C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>6</sub>-C<sub>60</sub> aryloxy group, a C<sub>6</sub>-C<sub>60</sub> arylthio group, a C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C<sub>1</sub>-C<sub>60</sub> alkyl group, a C<sub>2</sub>-C<sub>60</sub> alkenyl group, a C<sub>2</sub>-C<sub>60</sub> alkynyl group, a C<sub>1</sub>-C<sub>60</sub> alkoxy group, a C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>6</sub>-C<sub>60</sub> aryloxy group, a C<sub>6</sub>-C<sub>60</sub> arylthio group, a C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —Si(Q<sub>21</sub>)(Q<sub>22</sub>)(Q<sub>23</sub>), —N(Q<sub>21</sub>)(Q<sub>22</sub>), —B(Q<sub>21</sub>)(Q<sub>22</sub>), —C(=O)(Q<sub>21</sub>), —S(=O)<sub>2</sub>(Q<sub>21</sub>), and —P(=O)(Q<sub>21</sub>)(Q<sub>22</sub>); and —Si(Q<sub>31</sub>)(Q<sub>32</sub>)(Q<sub>33</sub>), —N(Q<sub>31</sub>)(Q<sub>32</sub>), —B(Q<sub>31</sub>)(Q<sub>32</sub>), —C(=O)(Q<sub>31</sub>), —S(=O)<sub>2</sub>(Q<sub>31</sub>), and —P(=O)(Q<sub>31</sub>)(Q<sub>32</sub>),

wherein Q<sub>1</sub> to Q<sub>3</sub>, Q<sub>11</sub> to Q<sub>13</sub>, Q<sub>21</sub> to Q<sub>23</sub>, and Q<sub>31</sub> to Q<sub>33</sub> 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<sub>1</sub>-C<sub>60</sub> alkyl group, a C<sub>2</sub>-C<sub>60</sub> alkenyl group, a C<sub>2</sub>-C<sub>60</sub> alkynyl group, a C<sub>1</sub>-C<sub>60</sub> alkoxy group, a C<sub>3</sub>-C<sub>10</sub> cycloalkyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkyl group, a C<sub>3</sub>-C<sub>10</sub> cycloalkenyl group, a C<sub>1</sub>-C<sub>10</sub> heterocycloalkenyl group, a C<sub>6</sub>-C<sub>60</sub> aryl group, a C<sub>1</sub>-C<sub>60</sub> heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

2. The condensed-cyclic compound as claimed in claim 1, wherein A<sub>1</sub> to A<sub>4</sub> are each independently selected from a benzene group, a naphthalene group, an anthracene group, a pyridine group, a pyridazine group, a pyrimidine group, a pyrazine group, a triazine group, a quinoline group, an isoquinoline group, a phthalazine group, naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a benzothiophene group, a benzofuran group, a dibenzothiophene group, and a dibenzofuran group.

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

A<sub>1</sub> and A<sub>3</sub> are identical to each other, and

A<sub>2</sub> and A<sub>4</sub> are identical to each other.

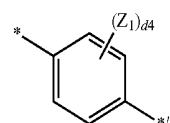
4. The condensed-cyclic compound as claimed in claim 1, wherein L<sub>1</sub> to L<sub>4</sub> are each independently selected from:

a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylylene group, a fluoranthenylylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylylene group, a hexacenylylene group, a furanylylene group, a carbazolylylene group, an indolylylene group, an isoindolylylene group, a benzofuranylylene group, a benzothiophenylylene group, a dibenzofuranylylene group, a dibenzothiophenylylene group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, a pyridinylylene group, an imidazolylylene group, a pyrazolylylene group, a thiazolylylene group, an isothiazolylylene group, an oxazolylylene group, an isoxazolylylene group, a thiadiazolylylene group, an oxadiazolylylene group, a pyrazinylylene group, a pyrimidinylylene group, a pyridazinylylene group, a triazinylylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylylene group, a naphthyridinylylene group, a quinoxalinylylene group, a quinazolinylylene group, a cinolinylene group, a phenanthridinylylene group, an acridinylylene group, a phenanthrolinylylene group, a phenazinylylene group, a benzimidazolylylene group, an isobenzothiazolylylene group, a benzoxazolylylene group, an isobenzoxazolylylene group, a triazolylylene group, a tetrazolylylene group, an imidazopyridinylylene group, an imidazopyrimidinylylene group, and an azacarbazolylylene group; and

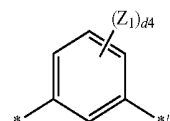
a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylylene group, a dibenzofluorenylylene group, a phenanthrenylene group, an anthracenylylene group, a fluoranthenylylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylylene group, a hexacenylylene group, a furanylylene group, a carbazolylylene group, an indolylylene group, an isoindolylylene group, a benzofuranylylene group, a benzothiophenylylene group, a dibenzofuranylylene group, a dibenzothiophenylylene group, a benzocarbazolylylene group, a dibenzocarbazolylylene group, a dibenzosilolylylene group, a pyridinylylene group, an imidazolylylene group, a pyrazolylylene group, a thiazolylylene group, an isothiazolylylene group, an oxazolylylene group, an isoxazolylylene group, a thiadiazolylylene group, an oxadiazolylylene group, a pyrazinylylene group, a pyrimidinylylene group, a pyridazinylylene group, a triazinylylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylylene group, a naphthyridinylylene group, a quinoxalinylylene group, a quinazolinylylene group, a cinolinylene group, a phenanthridinylylene group, an acridinylylene group, a phenanthrolinylylene group, a phenazinylylene group, a benzimidazolylylene group, an isobenzothiazolylylene group, a benzoxazolylylene group,

an isobenzoxazolylylene group, a triazolylylene group, a tetrazolylylene group, an imidazopyridinylylene group, an imidazopyrimidinylylene group, and an azacarbazolylylene 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<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>1</sub>-C<sub>20</sub> alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinylylene group, a quinazolinylylene group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinylylene 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.

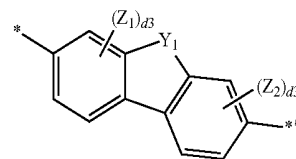
5. The condensed-cyclic compound as claimed in claim 1, wherein L<sub>1</sub> to L<sub>4</sub> are each independently a group represented by one of Formulae 3-1 to 3-4:



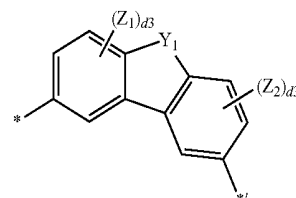
Formula 3-1



Formula 3-2

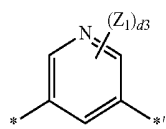
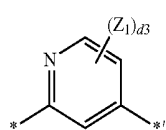
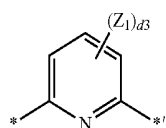
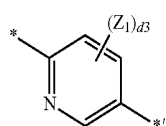
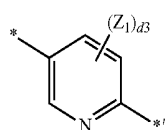
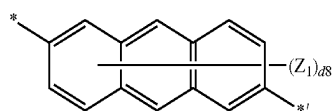
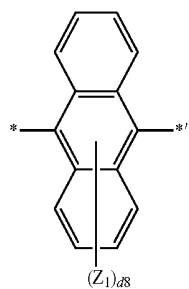
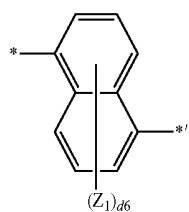
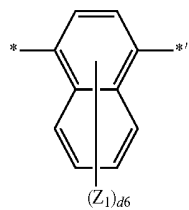
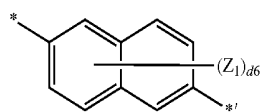


Formula 3-3



Formula 3-4

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Formula 3-5

Formula 3-6

Formula 3-7

Formula 3-8

Formula 3-9

Formula 3-10

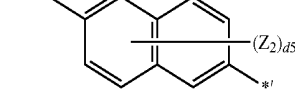
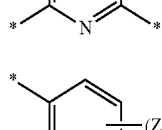
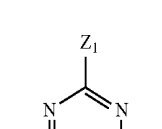
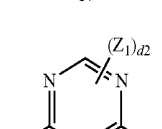
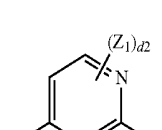
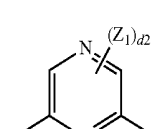
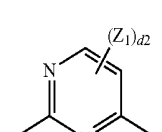
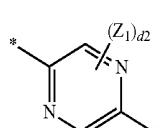
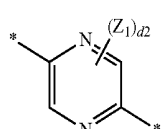
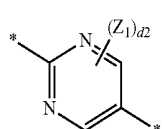
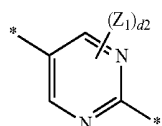
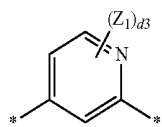
Formula 3-11

Formula 3-12

Formula 3-13

Formula 3-14

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Formula 3-15

Formula 3-16

Formula 3-17

Formula 3-18

Formula 3-19

Formula 3-20

Formula 3-21

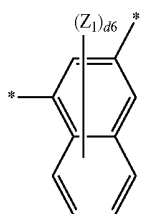
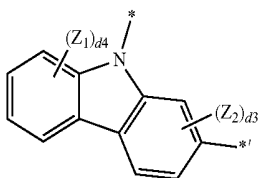
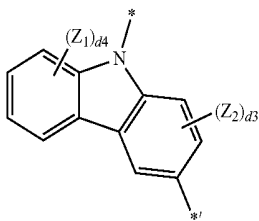
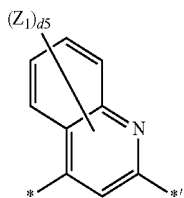
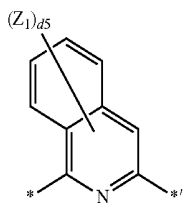
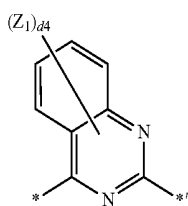
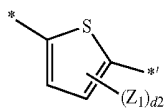
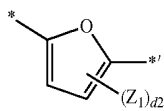
Formula 3-22

Formula 3-23

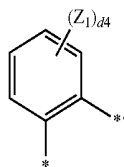
Formula 3-24

Formula 3-25

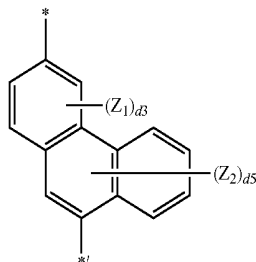
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Formula 3-26

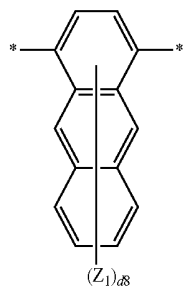


Formula 3-27



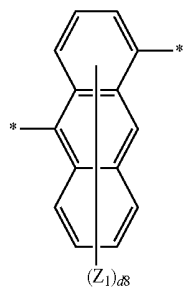
Formula 3-28

Formula 3-29

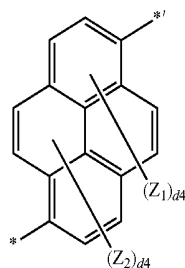


Formula 3-30

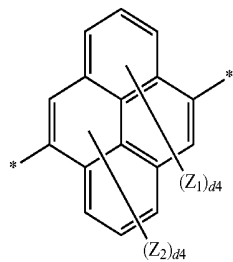
Formula 3-31



Formula 3-32



Formula 3-33



-continued

Formula 3-34

Formula 3-35

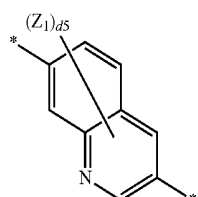
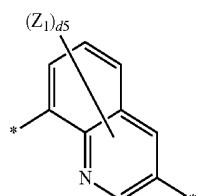
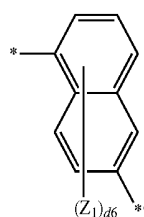
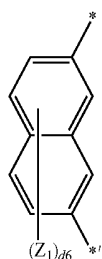
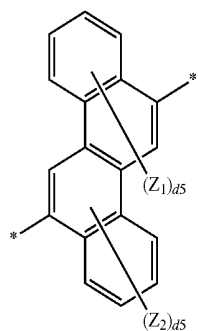
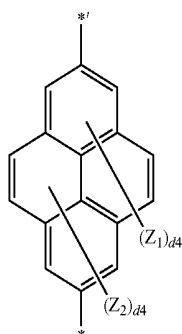
Formula 3-36

Formula 3-37

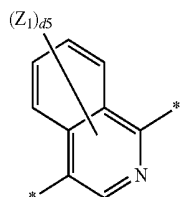
Formula 3-38

Formula 3-39

-continued



Formula 3-40



-continued

Formula 3-46

wherein, in Formulae 3-1 to 3-46,

Y<sub>1</sub> is selected from O, S, C(Z<sub>3</sub>)(Z<sub>4</sub>), N(Z<sub>5</sub>), and Si(Z<sub>6</sub>)(Z<sub>7</sub>),

Z<sub>1</sub> to Z<sub>7</sub> 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<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>1</sub>-C<sub>20</sub> alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-benzofluorene-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an indolyl group, an isoindolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, an isoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinoxalinyl group, a benzoquinazoliny group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiofenyl group, a benzosilolyl group, a benzothiazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphthosilolyl group, a thiadiazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafuorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indenocarbazolyl group, and an indolocarbazolyl group,

d<sub>2</sub> is an integer of 0 to 2,d<sub>3</sub> is an integer of 0 to 3,

Formula 3-41

Formula 3-42

Formula 3-43

Formula 3-44

Formula 3-45

d4 is an integer of 1 to 4,

d5 is an integer of 1 to 5,

d6 is an integer of 1 to 5,

d8 is an integer of 1 to 8, and

\* and \*<sup>†</sup> each indicate a binding site to an adjacent atom.

6. The condensed-cyclic compound as claimed in claim 5, wherein L<sub>1</sub> to L<sub>4</sub> are each independently a group represented by one of Formulae 3-1, 3-2, and 3-34.

7. The condensed-cyclic compound as claimed in claim 1, wherein a1 to a3 are each independently 0, 1, or 2.

8. The condensed-cyclic compound as claimed in claim 1, wherein Ar<sub>1</sub> to Ar<sub>4</sub> are each independently selected from:

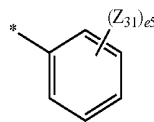
a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl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

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

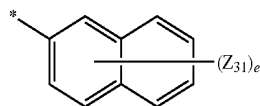
imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>1</sub>-C<sub>20</sub> alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthrenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinoxalinyl 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, and —Si(Q<sub>11</sub>)(Q<sub>12</sub>)(Q<sub>13</sub>),

wherein Q<sub>11</sub> to Q<sub>13</sub> are each independently selected from a C<sub>1</sub>-C<sub>10</sub> alkyl group, a C<sub>1</sub>-C<sub>10</sub> alkoxy group, a phenyl group, a biphenyl group, and a terphenyl group.

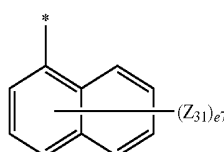
9. The condensed-cyclic compound as claimed in claim 1, wherein Ar<sub>1</sub> to Ar<sub>4</sub> are each independently a group represented by one of Formulae 5-1 to 5-79:



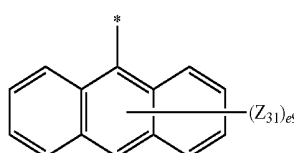
Formula 5-1



Formula 5-2

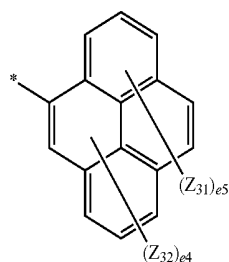
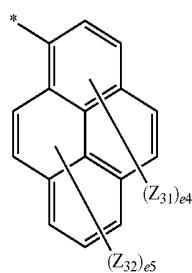
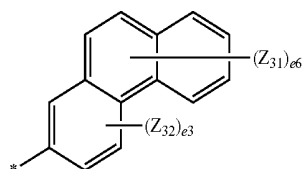
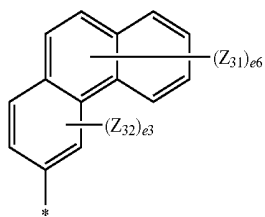
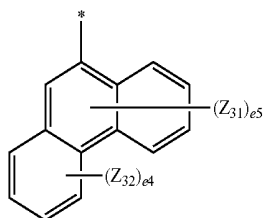
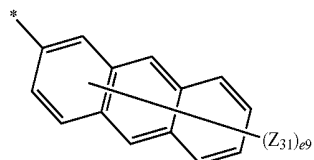
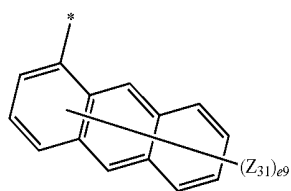


Formula 5-3



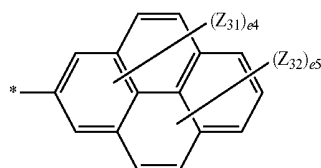
Formula 5-4

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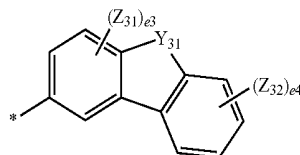


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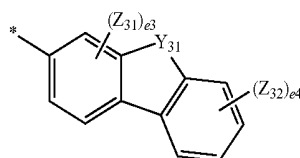
Formula 5-5



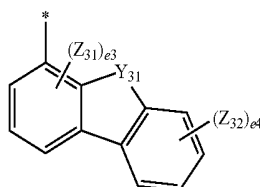
Formula 5-6



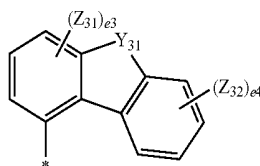
Formula 5-7



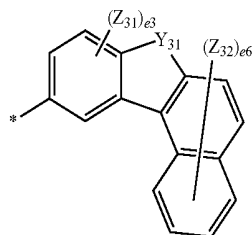
Formula 5-8



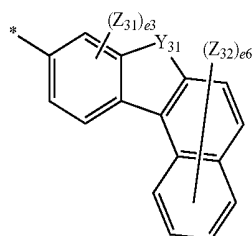
Formula 5-9



Formula 5-10



Formula 5-11



Formula 5-12

Formula 5-13

Formula 5-14

Formula 5-15

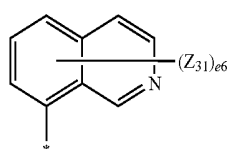
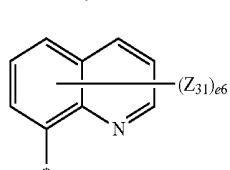
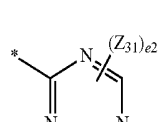
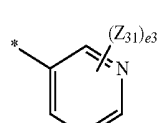
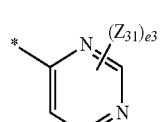
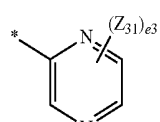
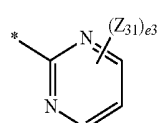
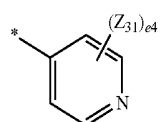
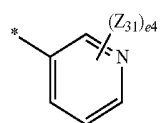
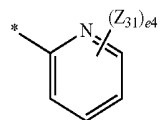
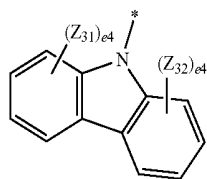
Formula 5-16

Formula 5-17

Formula 5-18

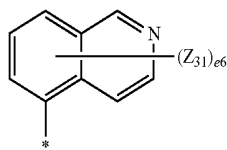
Formula 5-19

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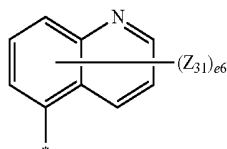


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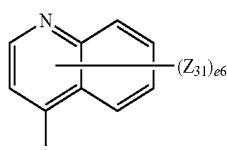
Formula 5-20



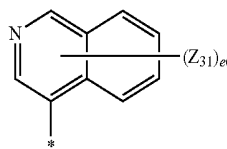
Formula 5-21



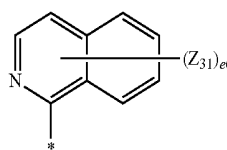
Formula 5-22



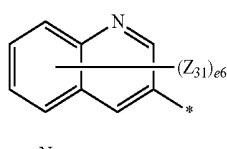
Formula 5-23



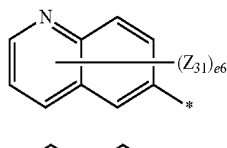
Formula 5-24



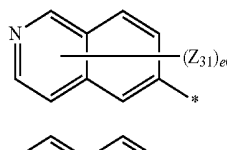
Formula 5-25



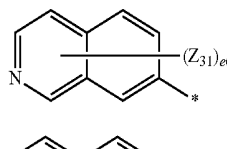
Formula 5-26



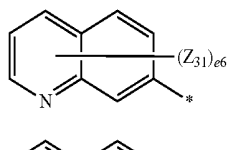
Formula 5-27



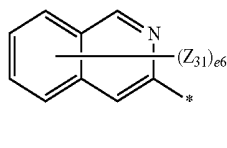
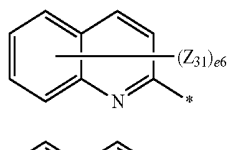
Formula 5-28



Formula 5-29



Formula 5-30



Formula 5-31

Formula 5-32

Formula 5-33

Formula 5-34

Formula 5-35

Formula 5-36

Formula 5-37

Formula 5-38

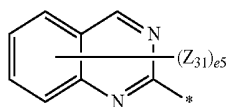
Formula 5-39

Formula 5-40

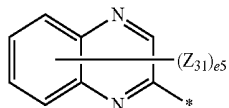
Formula 5-41

Formula 5-42

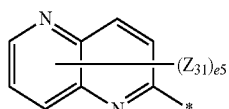
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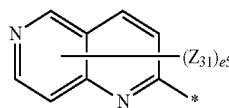
Formula 5-43



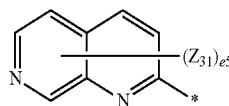
Formula 5-44



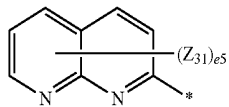
Formula 5-45



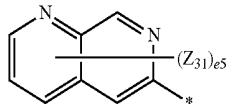
Formula 5-46



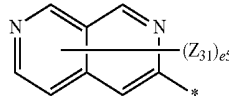
Formula 5-47



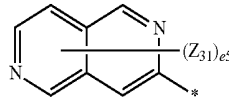
Formula 5-48



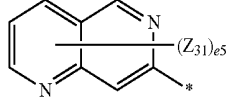
Formula 5-49



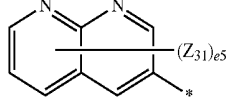
Formula 5-50



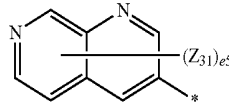
Formula 5-51



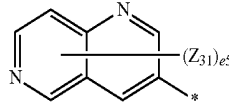
Formula 5-52



Formula 5-53

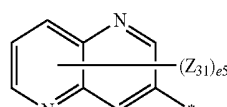


Formula 5-54

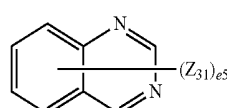


Formula 5-55

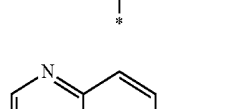
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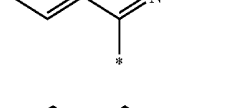
Formula 5-56



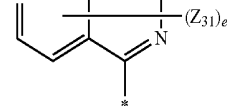
Formula 5-57



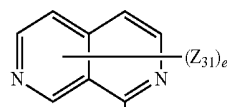
Formula 5-58



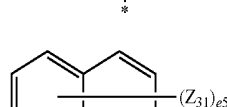
Formula 5-59



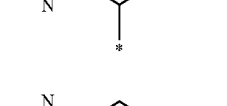
Formula 5-60



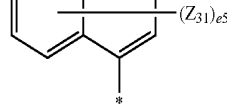
Formula 5-61



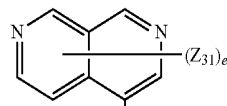
Formula 5-62



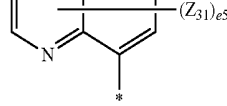
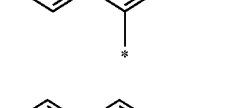
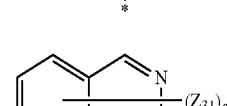
Formula 5-63



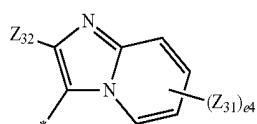
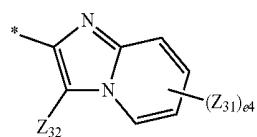
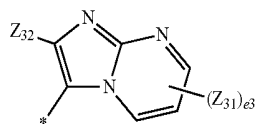
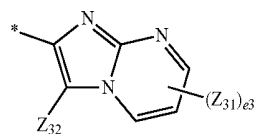
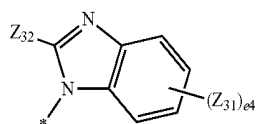
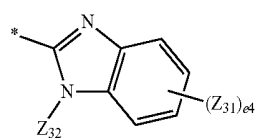
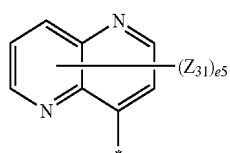
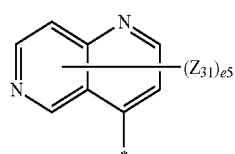
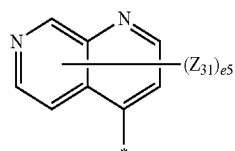
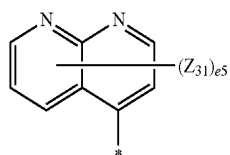
Formula 5-64



Formula 5-65

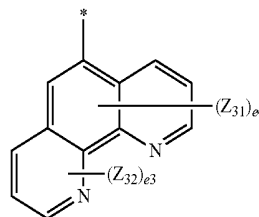


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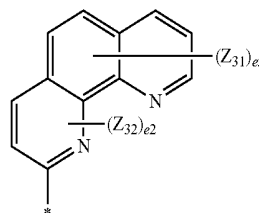


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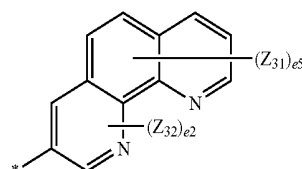
Formula 5-66



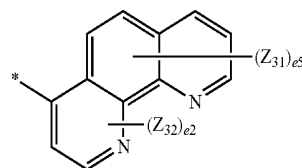
Formula 5-67



Formula 5-68



Formula 5-69



Formula 5-70

Formula 5-71

Formula 5-72

Formula 5-73

5-74

5-75

5-76

5-77

5-78

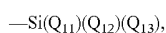
5-79

wherein, in Formulae 5-1 to 5-79,

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

$Z_{31}$ ,  $Z_{32}$ , and  $Z_{35}$  to  $Z_{39}$  are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a  $C_1$ - $C_{20}$  alkyl group, a  $C_1$ - $C_{20}$  alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-benzofluorene-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentacenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, a silolyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an indolyl group, an isoindolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, an isoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinoxalinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl

group, an acridinyl group, a phenanthrolyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiofenyl group, a benzosilolyl group, a benzothiazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, a naphthobenzofuranyl group, a naphthobenzothiophenyl group, a naphthobenzosilolyl group, a dibenzocarbazolyl group, a dinaphthofuranyl group, a dinaphthothiophenyl group, a dinaphthosilolyl group, a thiadiazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an oxazolopyridinyl group, a thiazolopyridinyl group, a benzonaphthyridinyl group, an azafuorenyl group, an azaspiro-bifluorenyl group, an azacarbazolyl group, an azadibenzofuranyl group, an azadibenzothiophenyl group, an azadibenzosilolyl group, an indenopyrrolyl group, an indolopyrrolyl group, an indenocarbazolyl group, and an indolocarbazolyl group; and



wherein  $\text{Q}_{11}$  to  $\text{Q}_{13}$  are each independently 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, and a terphenyl group,

$e_2$  is an integer of 0 and 2,

$e_3$  is an integer of 0 to 3,

$e_4$  is an integer of 0 to 4,

$e_5$  is an integer of 0 to 5,

$e_6$  is an integer of 0 to 6,

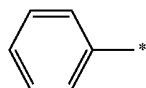
$e_7$  is an integer of 0 to 7,

$e_9$  is an integer of 0 to 9, and

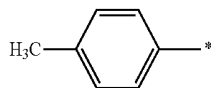
\* indicates a binding site to an adjacent atom.

10. The condensed-cyclic compound as claimed in claim 9, wherein  $\text{Ar}_1$  to  $\text{Ar}_4$  are each independently a group represented by one of Formulae 5-1 to 5-3, 5-13 to 5-19, and 5-21 to 5-28.

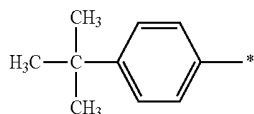
11. The condensed-cyclic compound as claimed in claim 1, wherein  $\text{Ar}_1$  to  $\text{Ar}_4$  are each independently a group represented by one of Formulae 6-1 to 6-14:



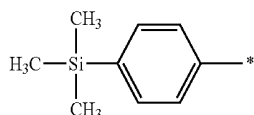
Formula 6-1



Formula 6-2

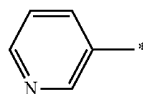


Formula 6-3

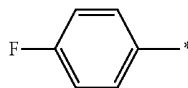


Formula 6-4

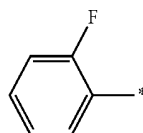
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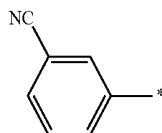
Formula 6-5



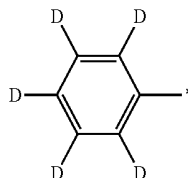
Formula 6-6



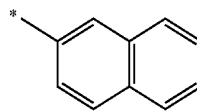
Formula 6-7



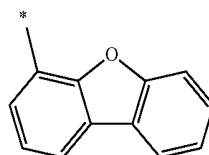
Formula 6-8



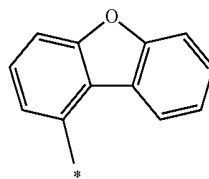
Formula 6-9



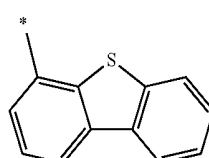
Formula 6-10



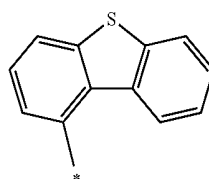
Formula 6-11



Formula 6-12



Formula 6-13



Formula 6-14

wherein \* indicates a binding site to an adjacent atom.

12. The condensed-cyclic compound as claimed in claim 1, wherein b1 to b4 are each independently an integer of 1 to 3.

13. The condensed-cyclic compound as claimed in claim 1, wherein R<sub>1</sub> to R<sub>6</sub> are each independently selected from:

—F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C<sub>1</sub>-C<sub>20</sub> alkyl group, and a C<sub>1</sub>-C<sub>20</sub> alkoxy group;

a C<sub>1</sub>-C<sub>20</sub> alkyl group and a C<sub>1</sub>-C<sub>20</sub> 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, and a hydrazono group;

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

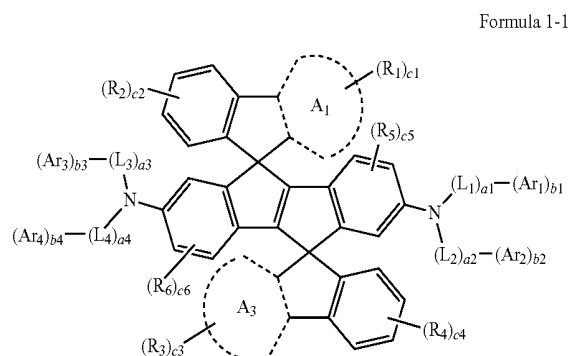
a cyclopentyl group, a cyclohexyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C<sub>1</sub>-C<sub>20</sub> alkyl group, a C<sub>1</sub>-C<sub>20</sub> alkoxy group, a cyclopentyl group, a cyclohexyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, and a terphenyl group; and

—Si(Q<sub>1</sub>)(Q<sub>2</sub>)(Q<sub>3</sub>),

wherein Q<sub>1</sub> to Q<sub>3</sub> are each independently selected from a C<sub>1</sub>-C<sub>10</sub> alkyl group, a C<sub>1</sub>-C<sub>10</sub> alkoxy group, a phenyl group, a biphenyl group, and a terphenyl group.

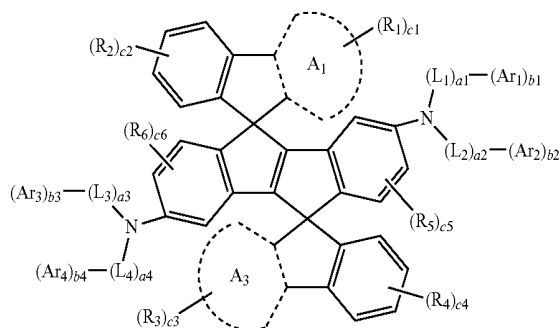
14. The condensed-cyclic compound as claimed in claim 1, wherein c1 to c6 in Formula 1 are each independently 0, 1, or 2.

15. The condensed-cyclic compound as claimed in claim 1, wherein the compound represented by Formula 1 is represented by Formula 1-1 or Formula 1-2:



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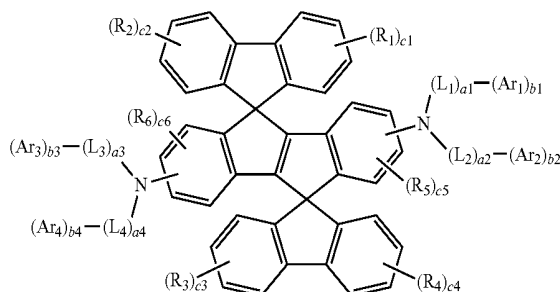
Formula 1-2



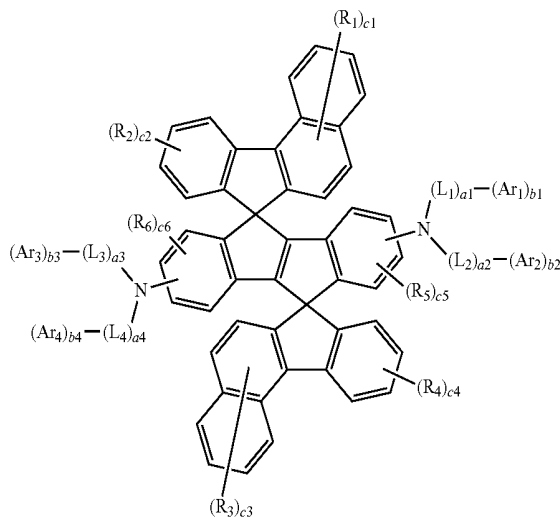
wherein, in Formulae 1-1 and 1-2, A<sub>1</sub>, A<sub>3</sub>, L<sub>1</sub> to L<sub>4</sub>, a1 to a4, Ar<sub>1</sub> to Ar<sub>4</sub>, b1 to b4, R<sub>1</sub> to R<sub>6</sub>, and c1 to c6 are defined the same as those of Formula 1.

16. The condensed-cyclic compound as claimed in claim 1, wherein the compound represented by Formula 1 is represented by one of Formulae 1(1) to 1(26):

Formula 1(1)

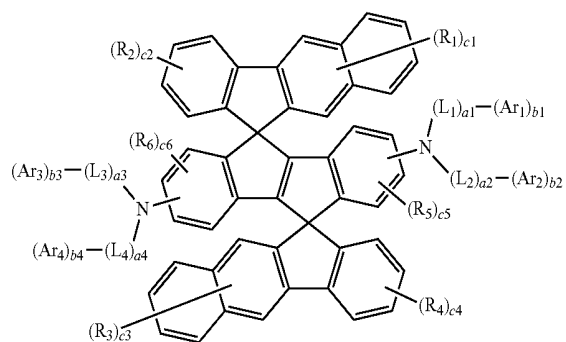


Formula 1(2)

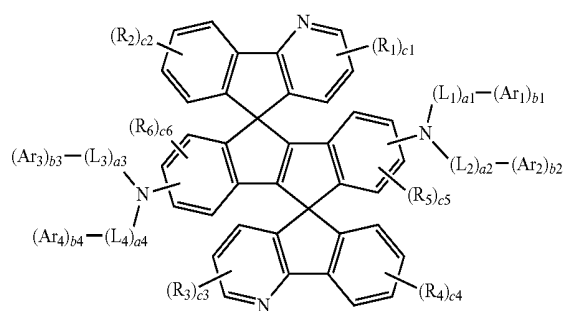


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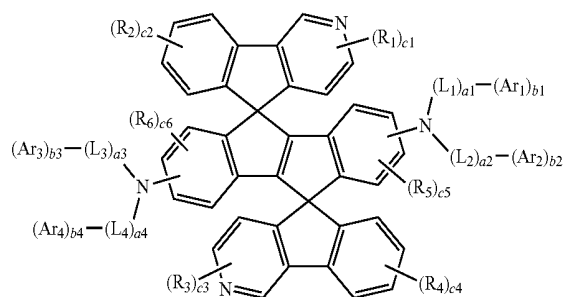
Formula 1(3)



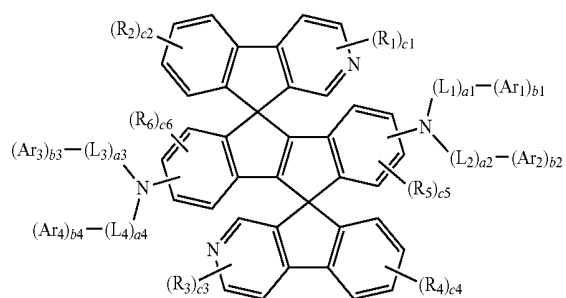
Formula 1(4)



Formula 1(5)

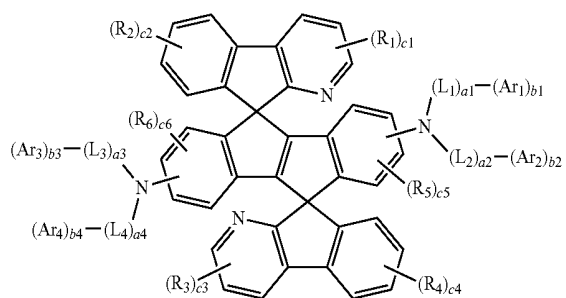


Formula 1(6)

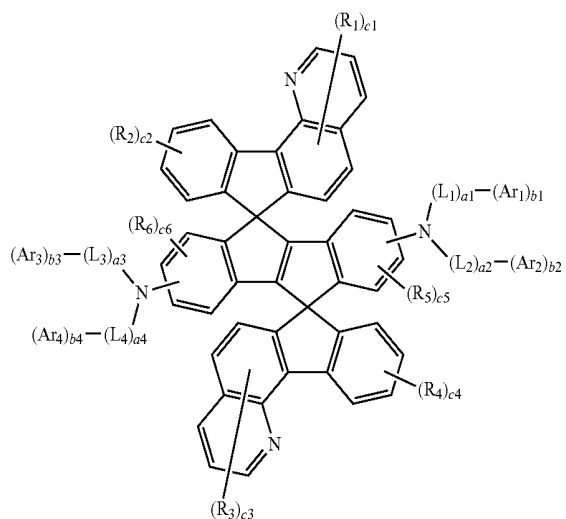


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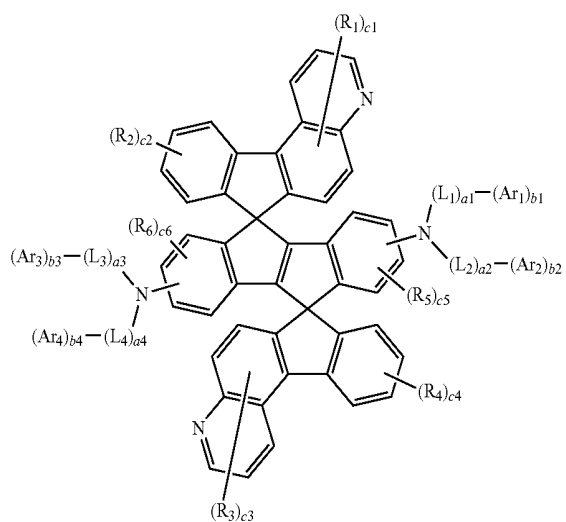
Formula 1(7)



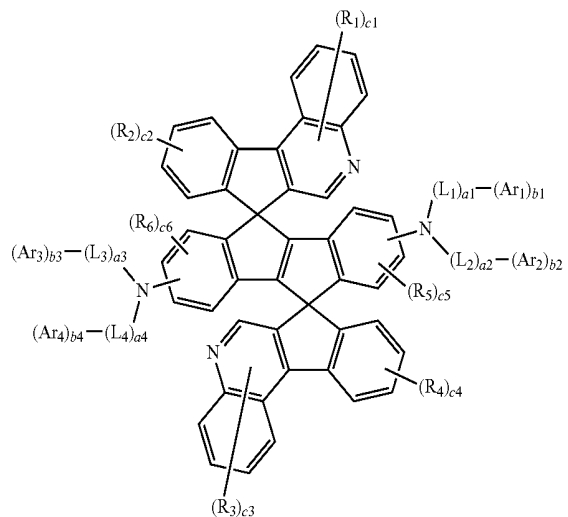
Formula 1(8)



Formula 1(9)

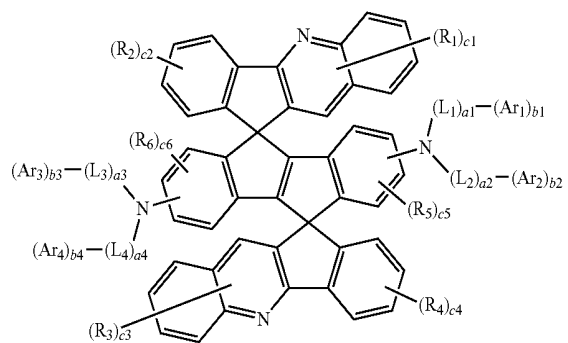


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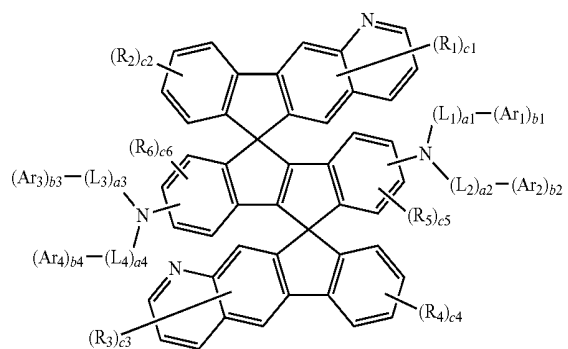


Formula 1(10)

Formula 1(11)

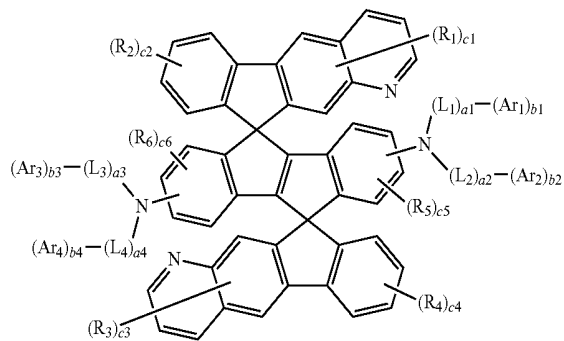


Formula 1(12)

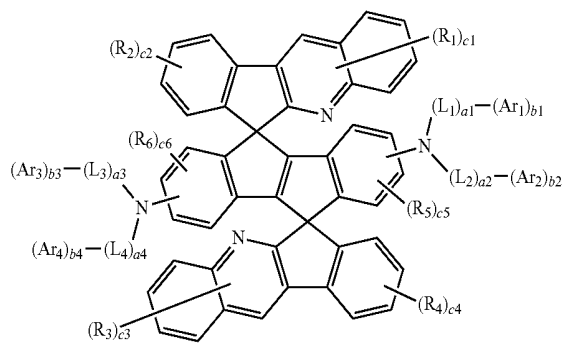


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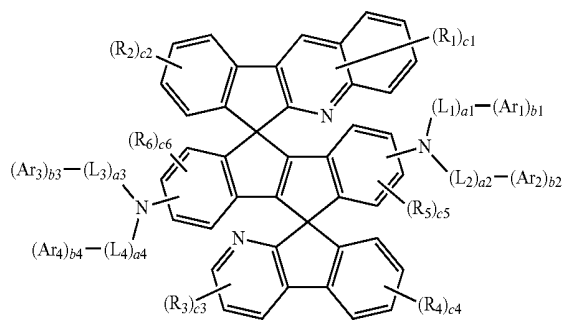
Formula 1(13)



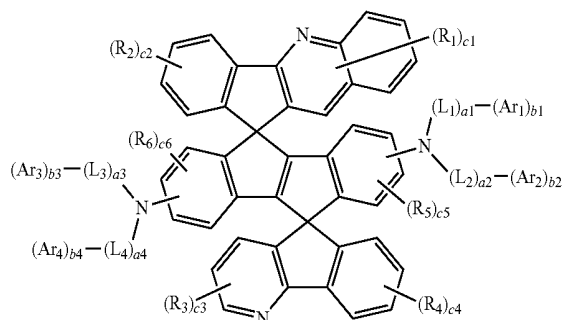
Formula 1(14)



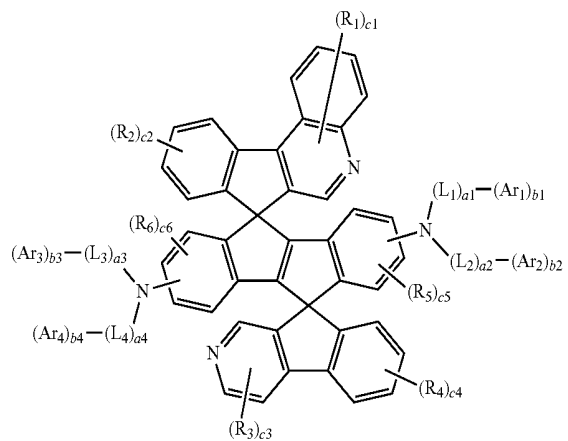
Formula 1(15)



Formula 1(16)

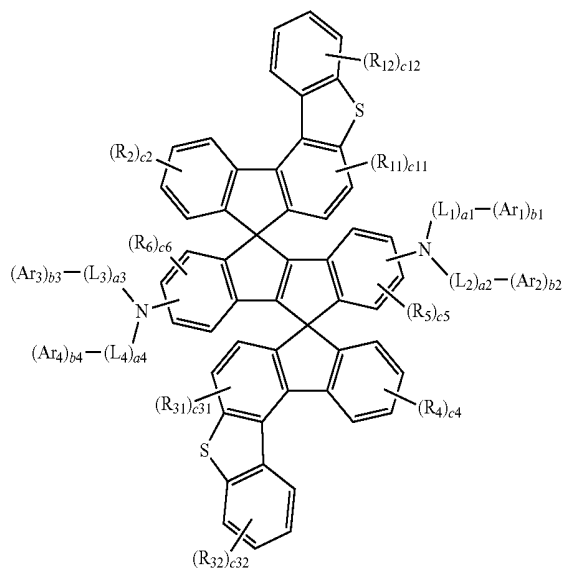


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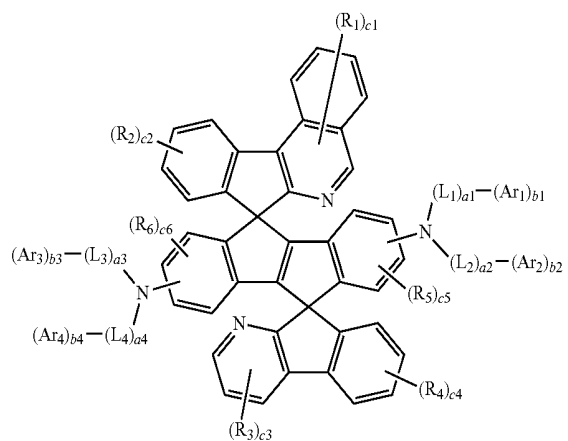
Formula 1(17)

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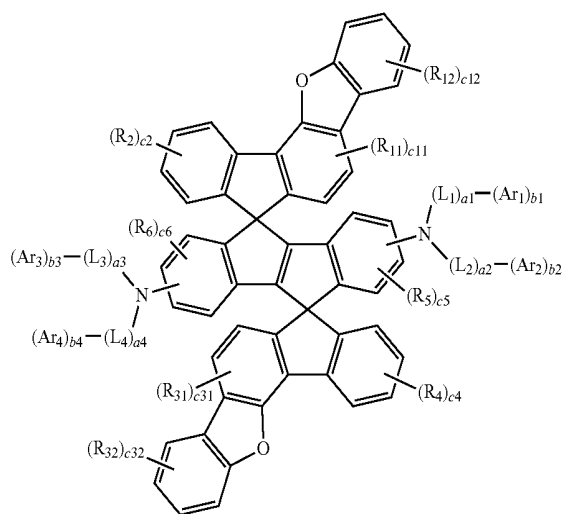


Formula 1(20)

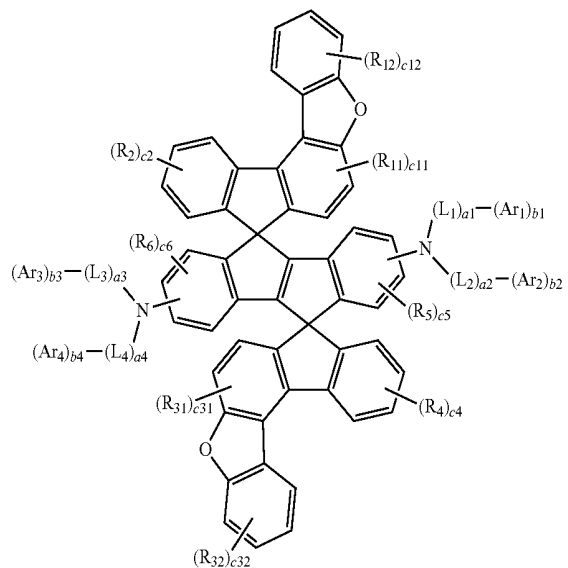
Formula 1(18)



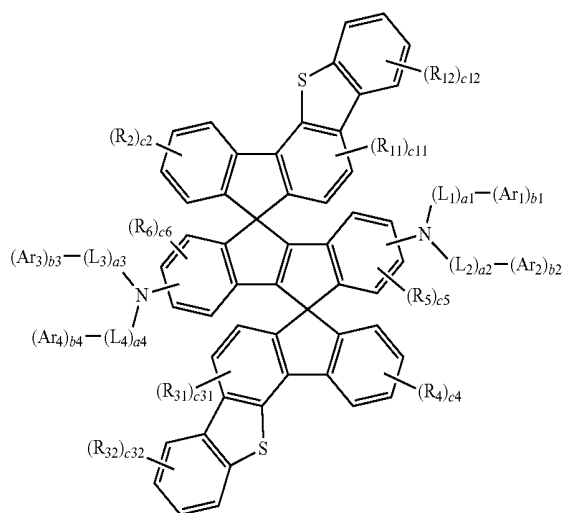
Formula 1(19)



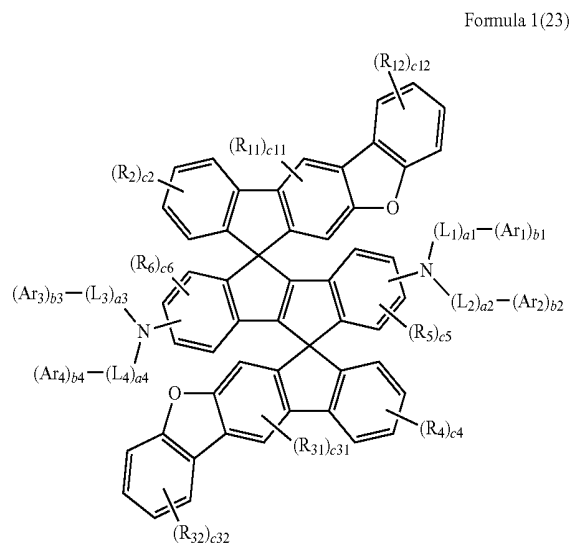
Formula 1(21)



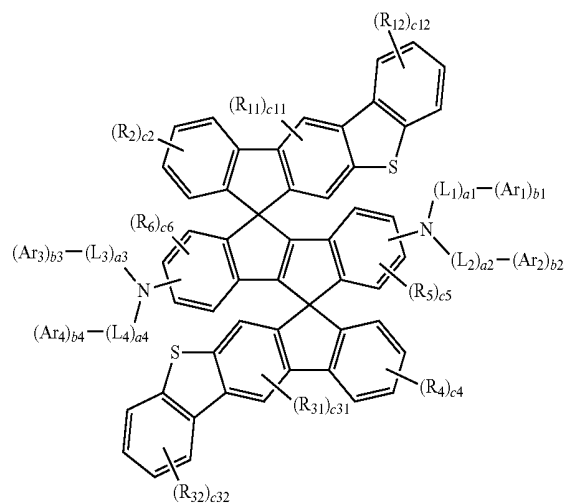
Formula 1(22)



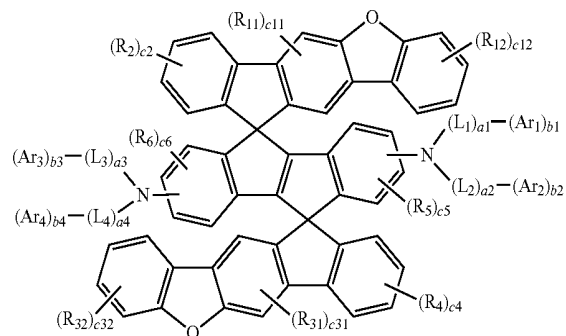
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Formula 1(24)

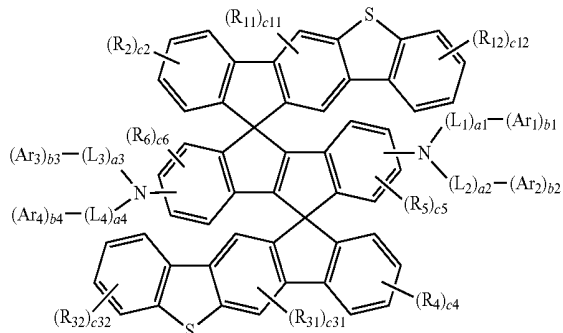


Formula 1(25)



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Formula 1(26)



wherein, in Formulae 1(1) to 1(18),

L<sub>1</sub> to L<sub>4</sub>, a<sub>1</sub> to a<sub>4</sub>, Ar<sub>1</sub> to Ar<sub>4</sub>, b<sub>1</sub> to b<sub>4</sub>, R<sub>1</sub> to R<sub>6</sub>, and c<sub>1</sub> to c<sub>6</sub> are defined the same as those of Formula 1,

wherein, in Formulae 1(19) and 1(26),

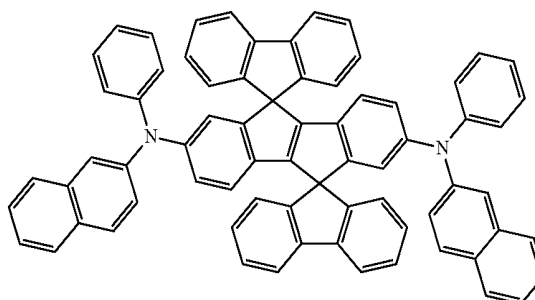
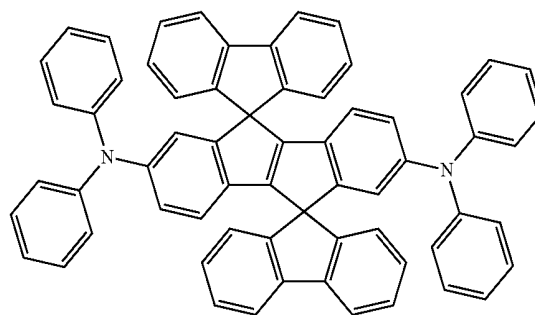
L<sub>1</sub> to L<sub>4</sub>, a<sub>1</sub> to a<sub>4</sub>, Ar<sub>1</sub> to Ar<sub>4</sub>, b<sub>1</sub> to b<sub>4</sub>, R<sub>2</sub>, R<sub>4</sub> to R<sub>6</sub>, c<sub>2</sub>, and c<sub>4</sub> to c<sub>6</sub> are defined the same as those of Formula 1,

R<sub>11</sub>, R<sub>12</sub>, R<sub>31</sub>, and R<sub>32</sub> are defined the same as R<sub>1</sub> and R<sub>3</sub> of Formula 1,

c<sub>11</sub> and c<sub>31</sub> are each independently an integer of 0 to 2, and

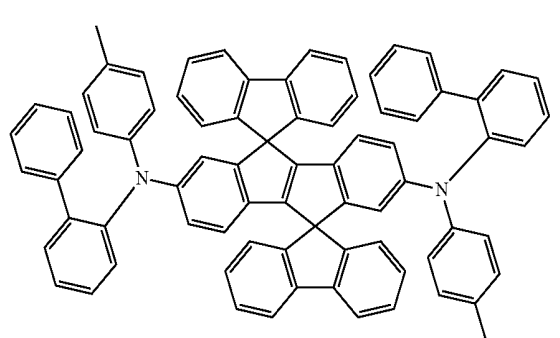
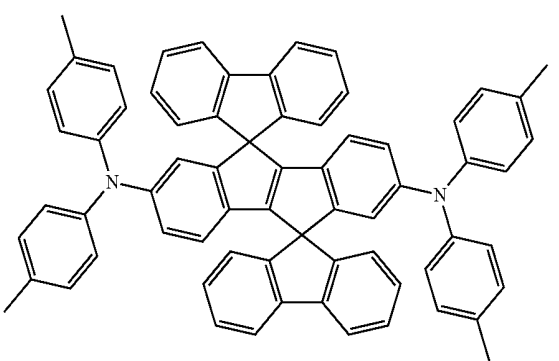
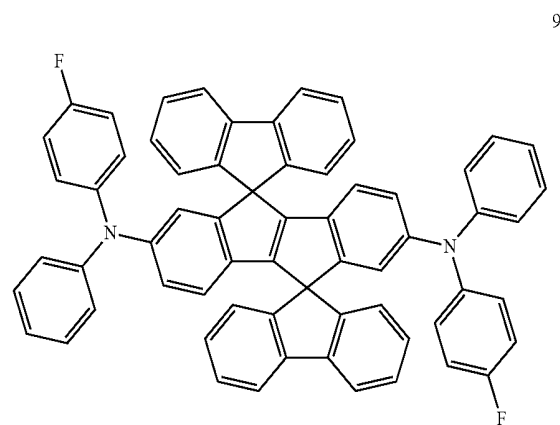
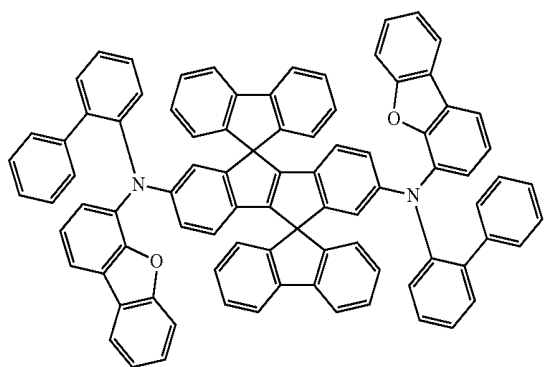
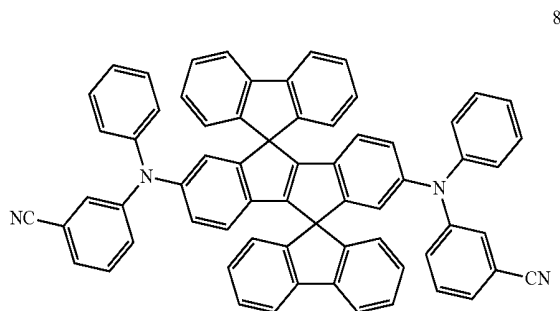
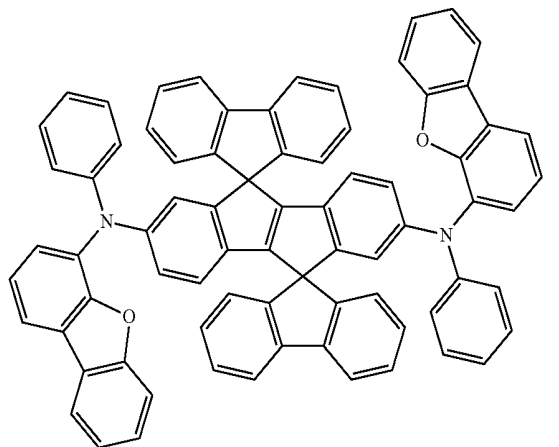
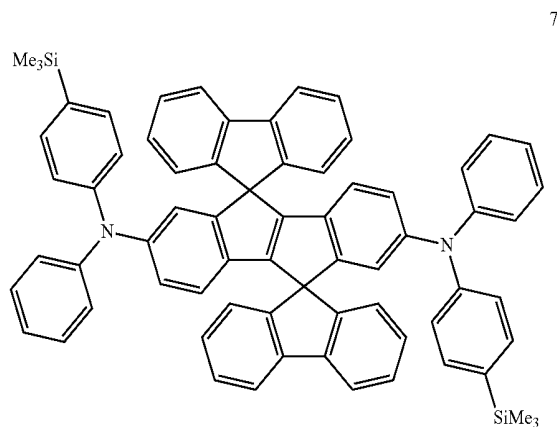
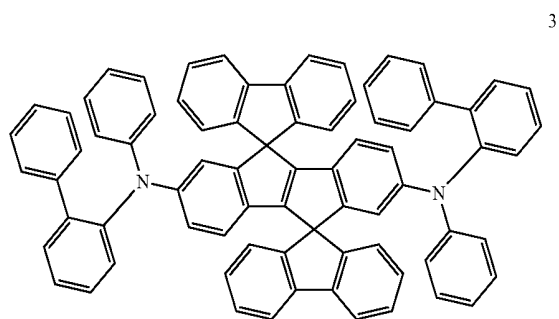
c<sub>12</sub> and c<sub>32</sub> are each independently an integer of 0 to 4.

17. The condensed-cyclic compound as claimed in claim 1, wherein the compound represented by Formula 1 is one of Compounds 1 to 69:



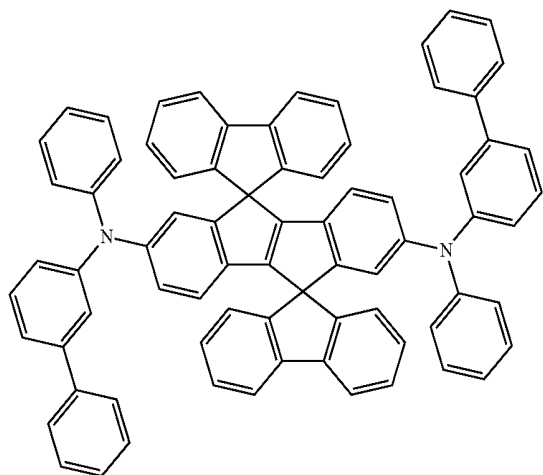
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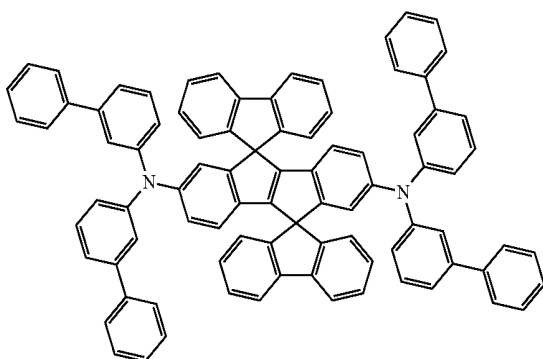


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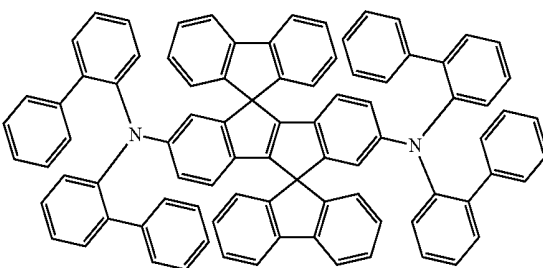
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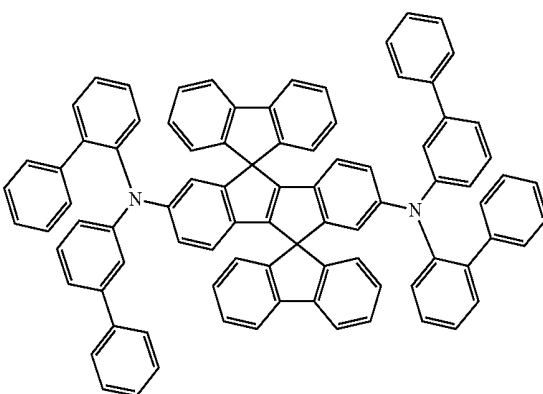
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13

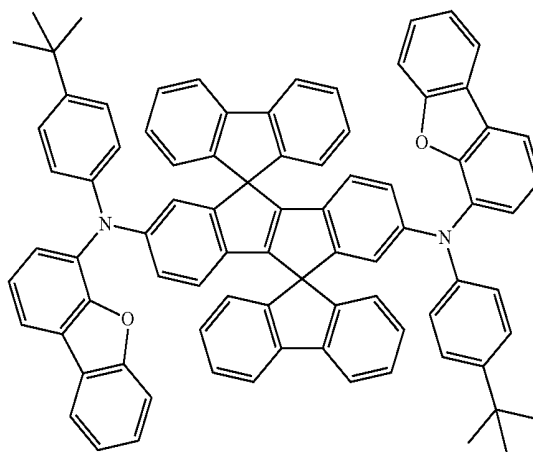


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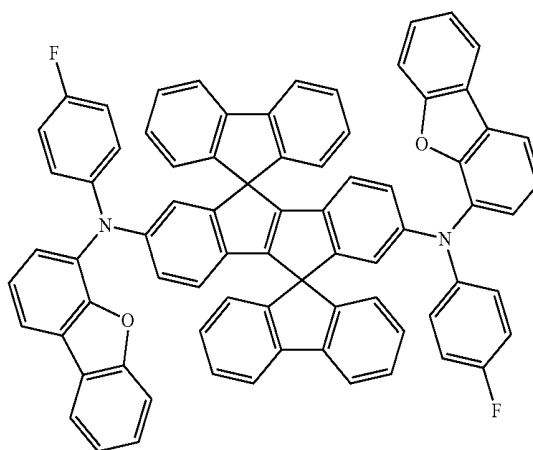


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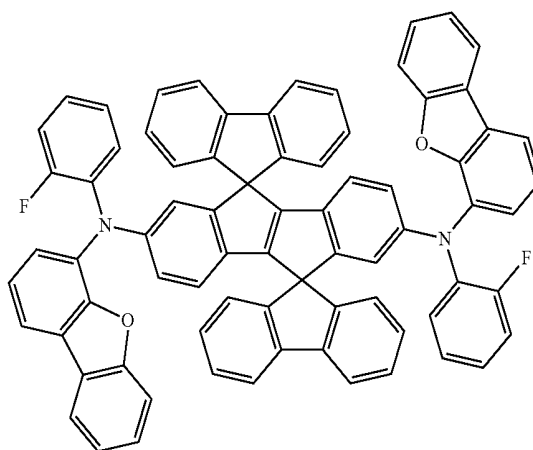
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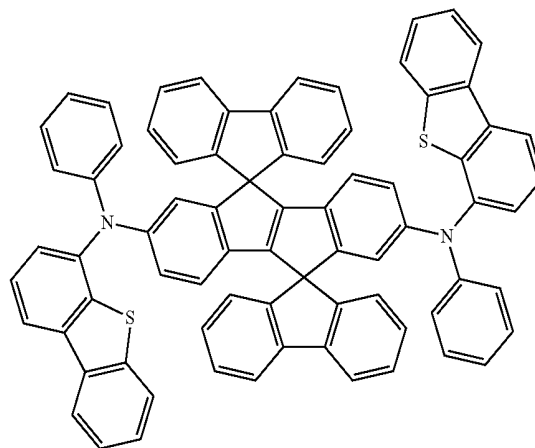
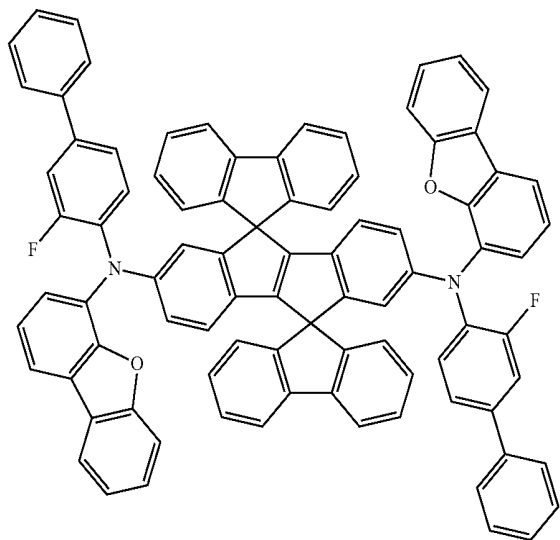


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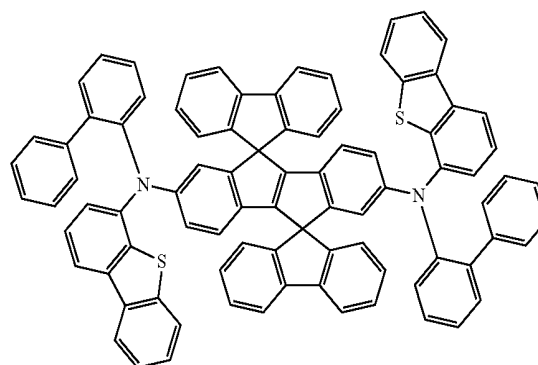
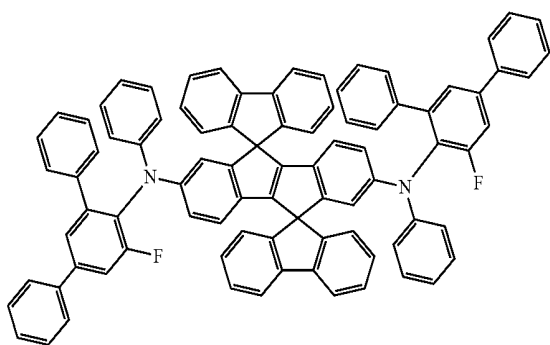
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22



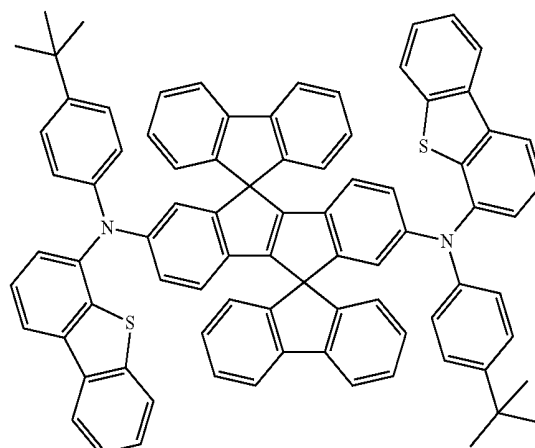
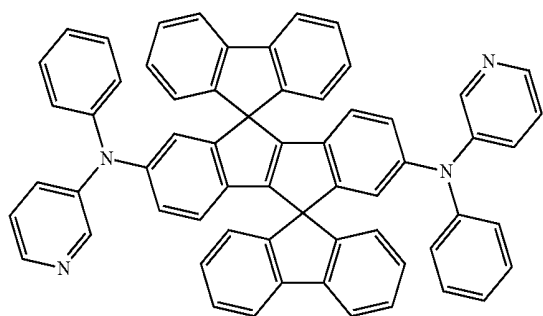
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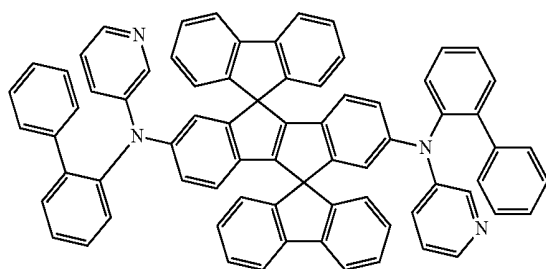


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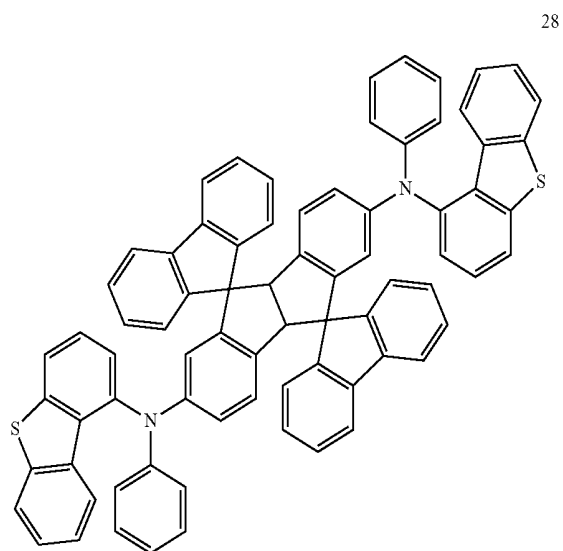
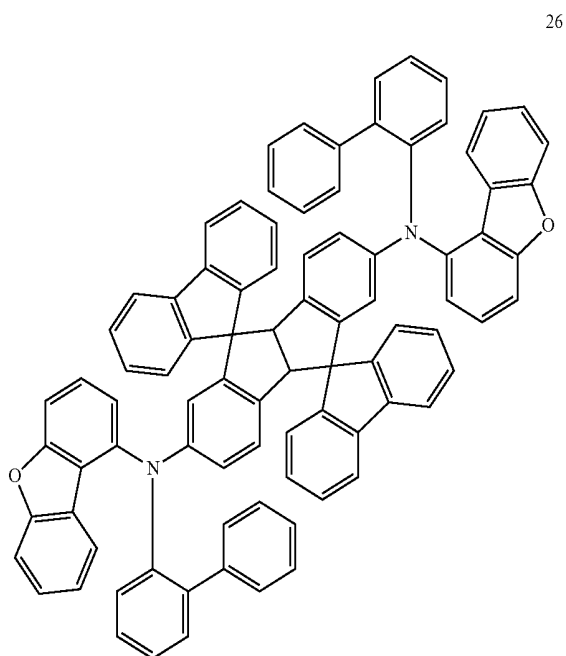
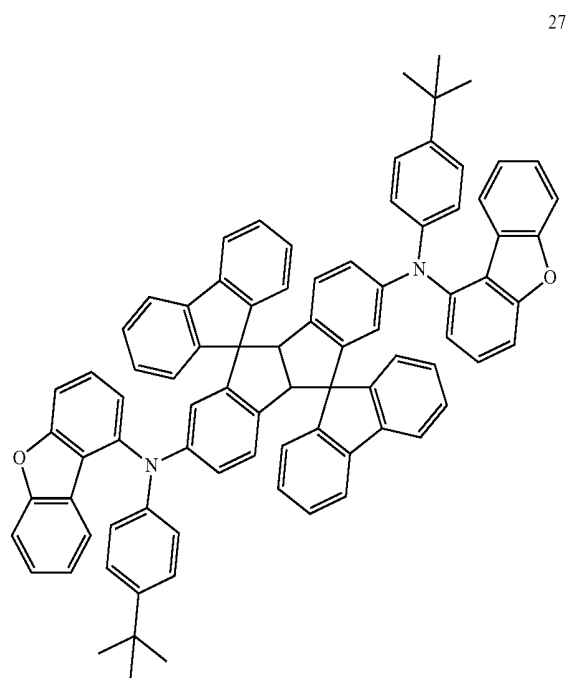
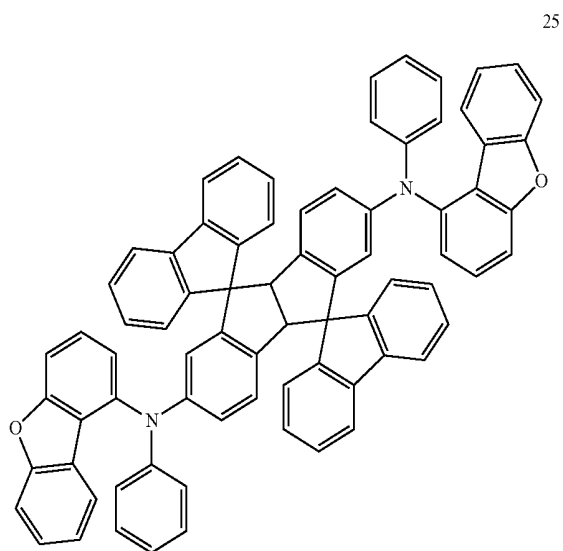


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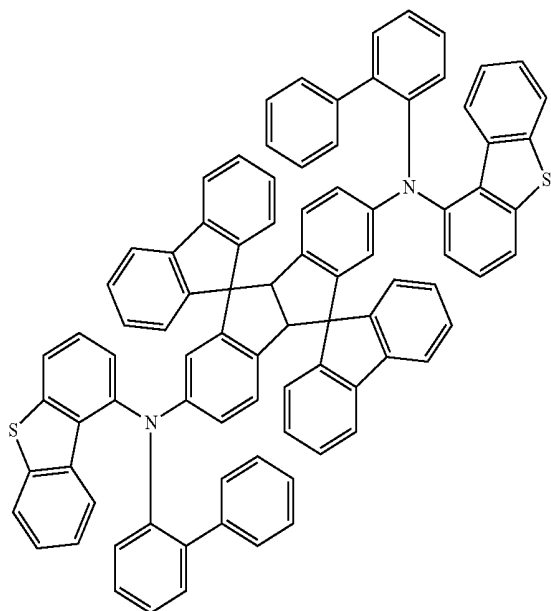
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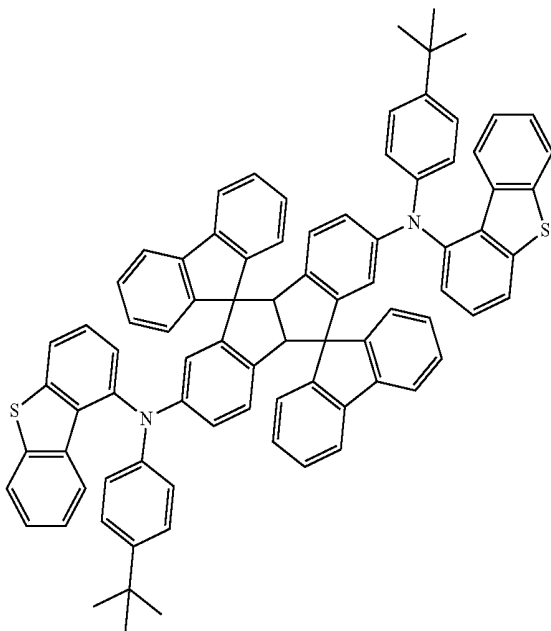


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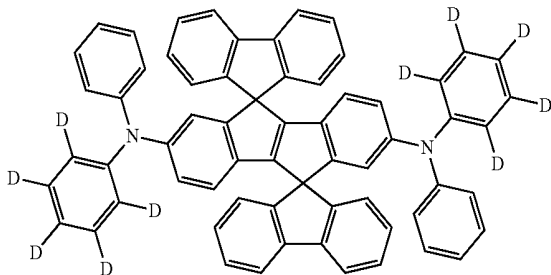
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30

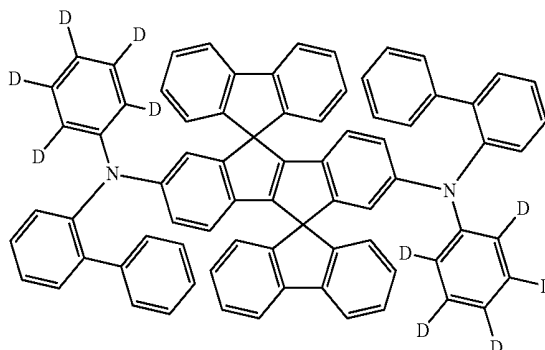


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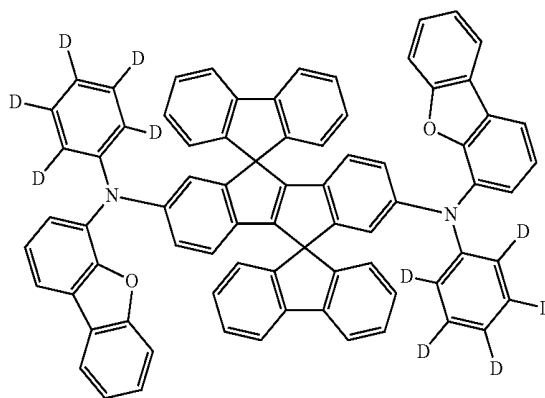


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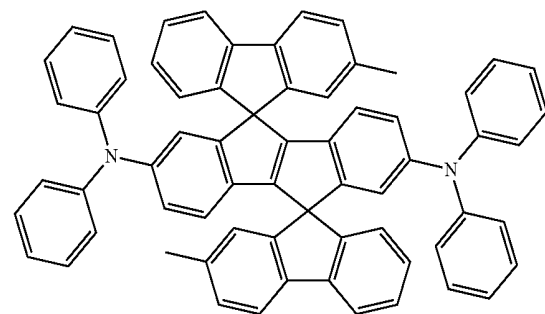
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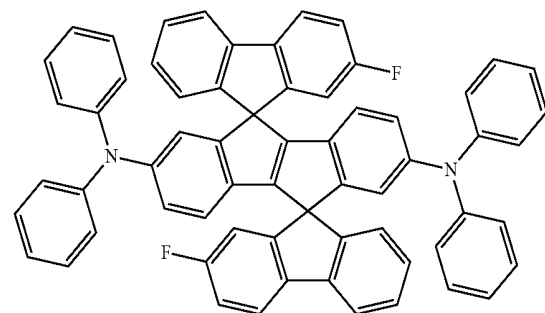
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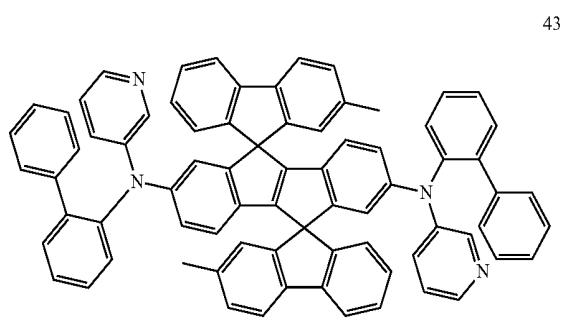
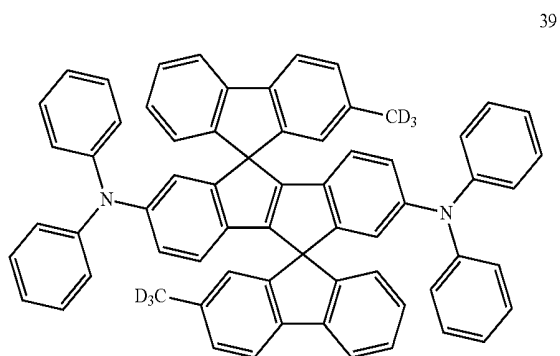
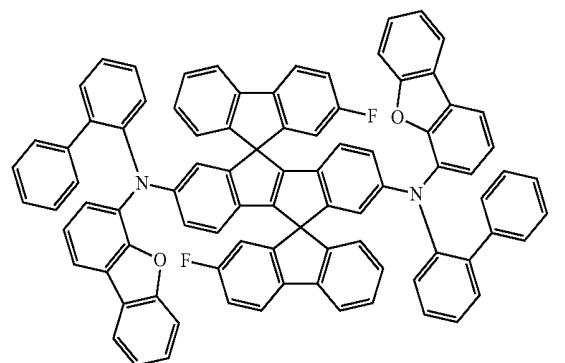
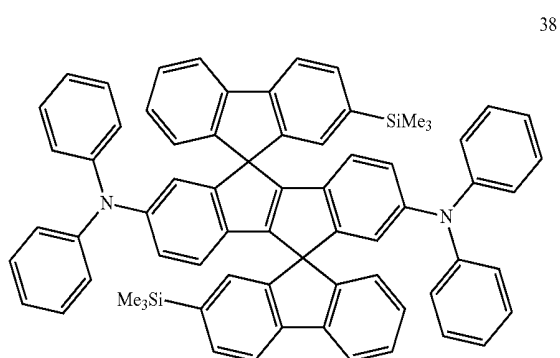
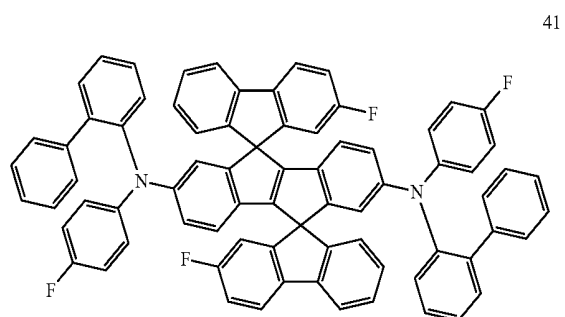
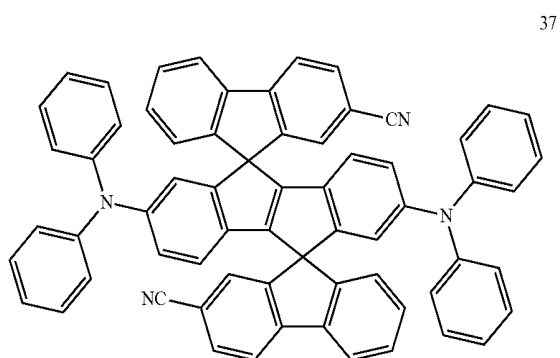
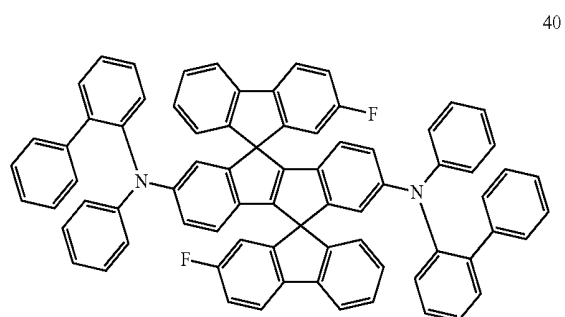
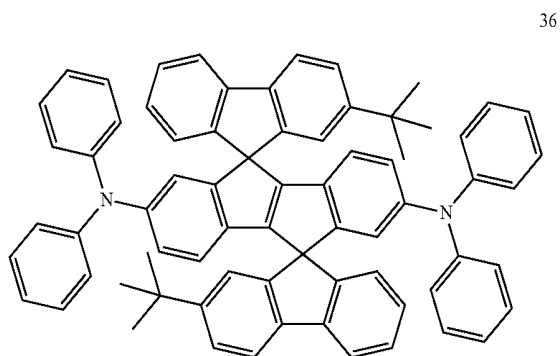


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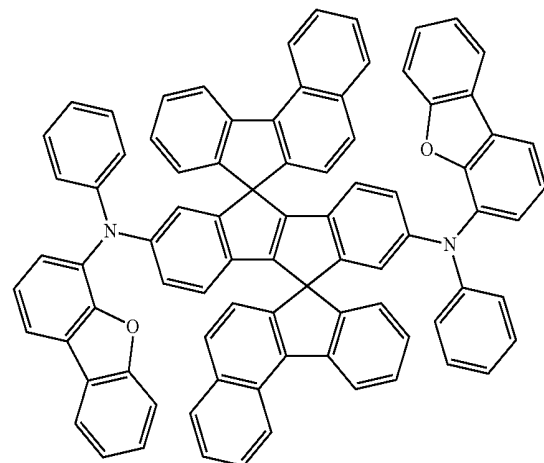
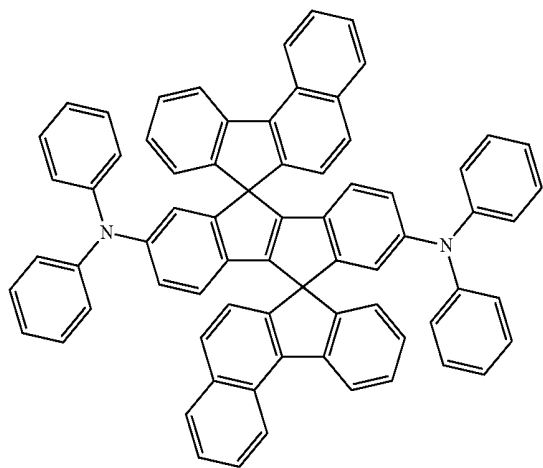
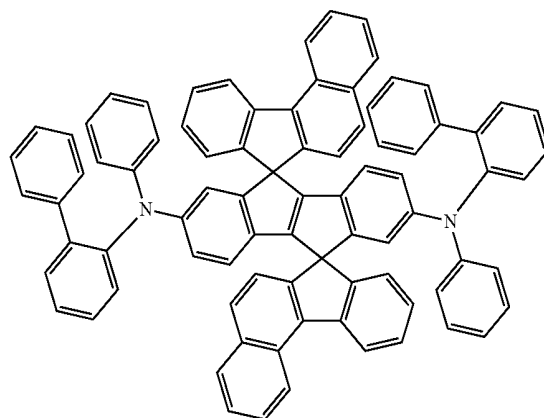
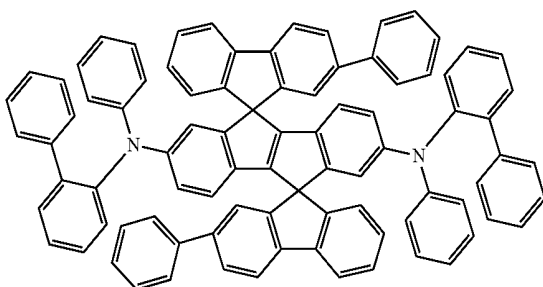
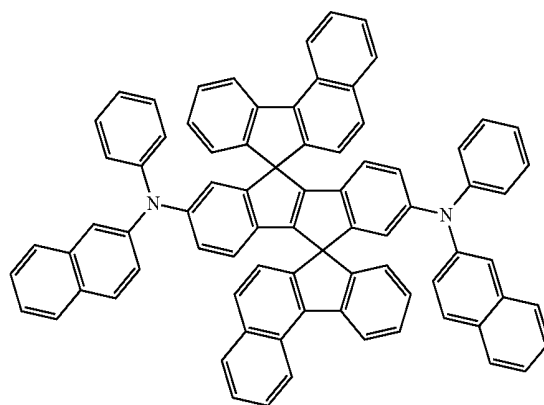
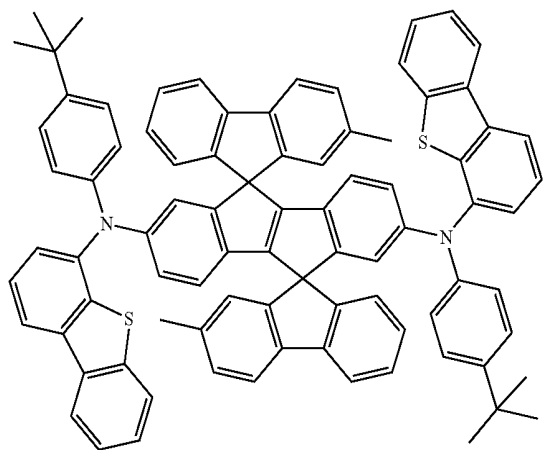
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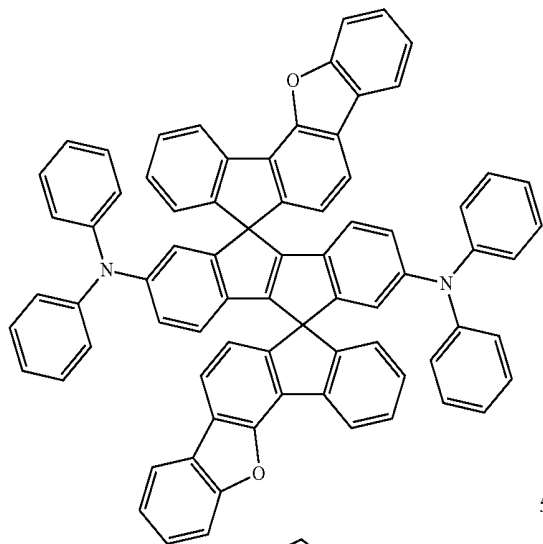
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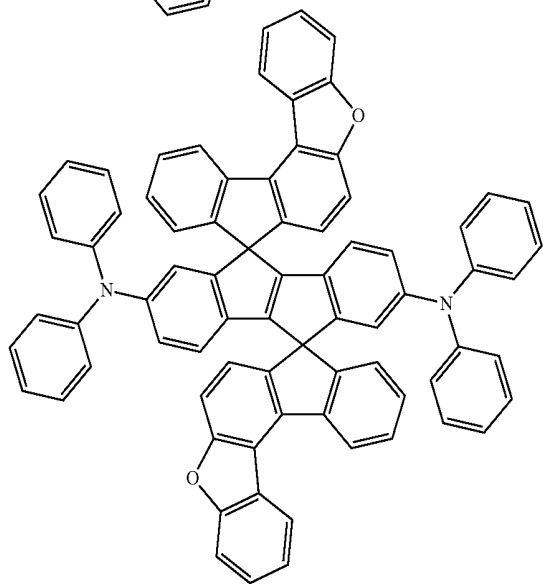


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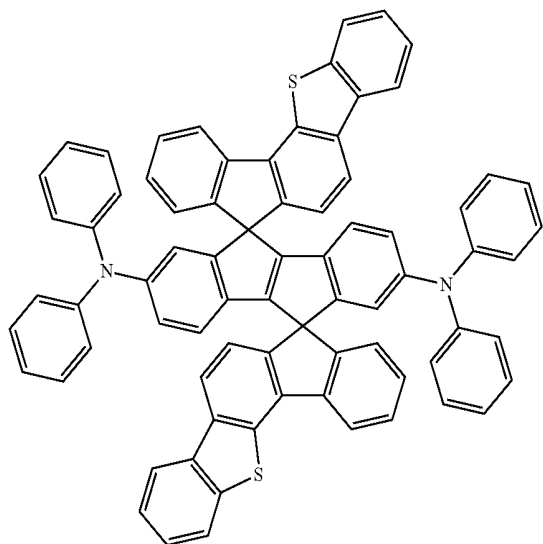
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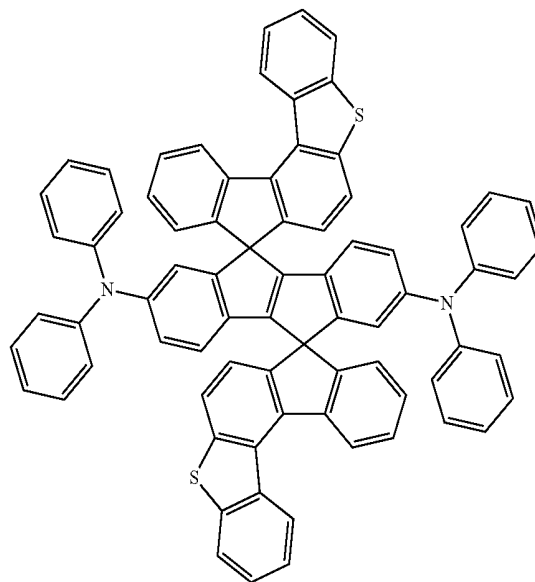


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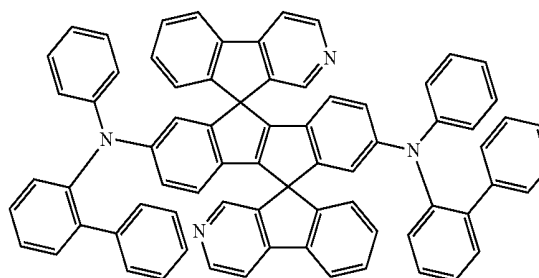


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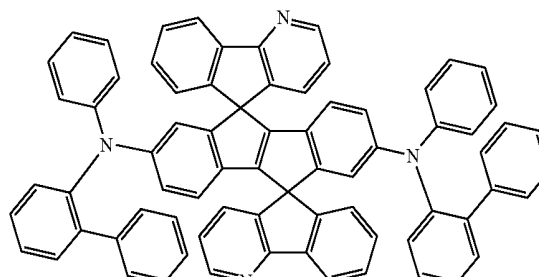
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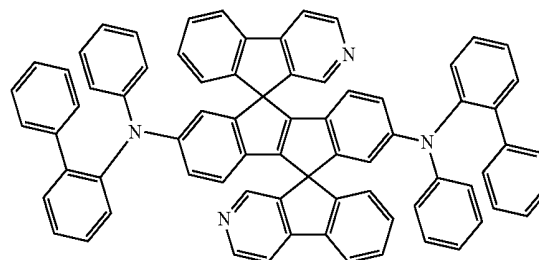
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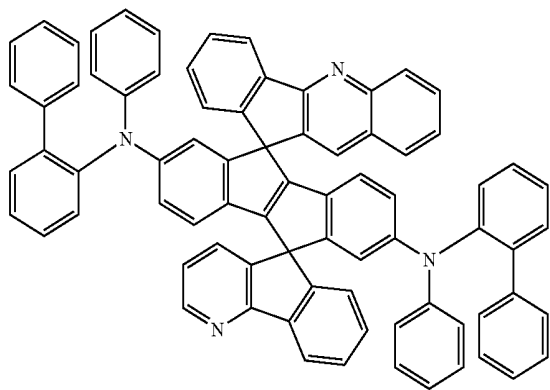
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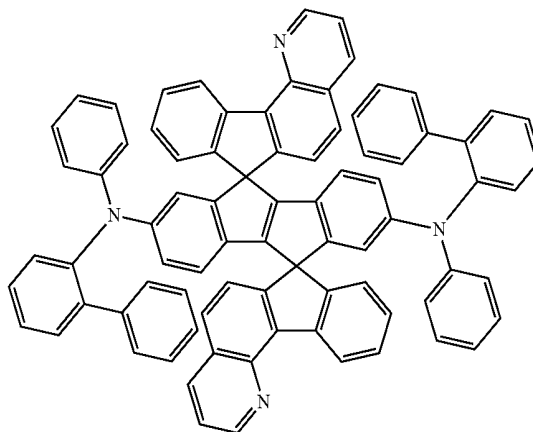
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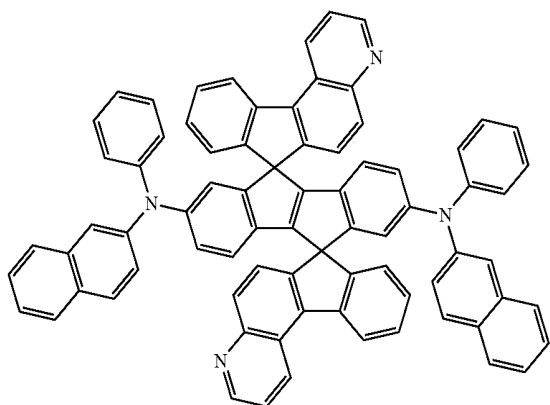
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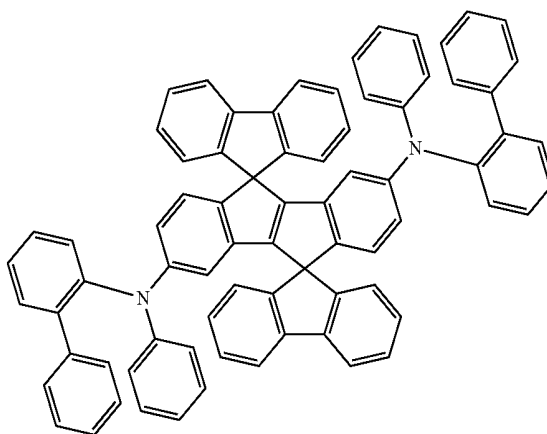
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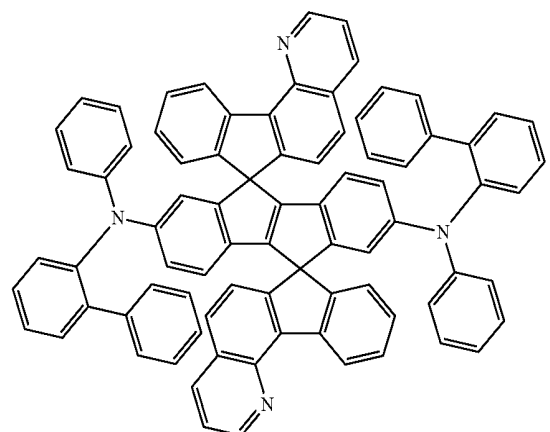
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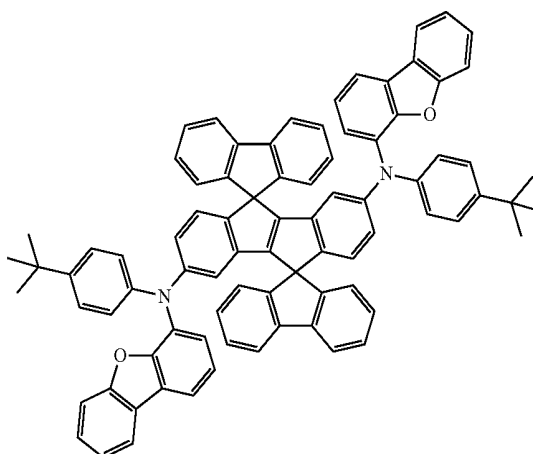
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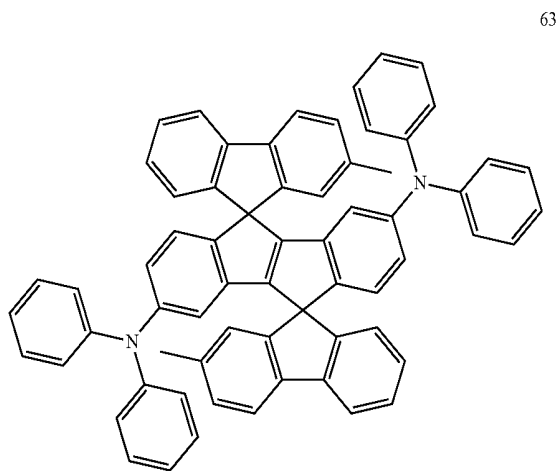
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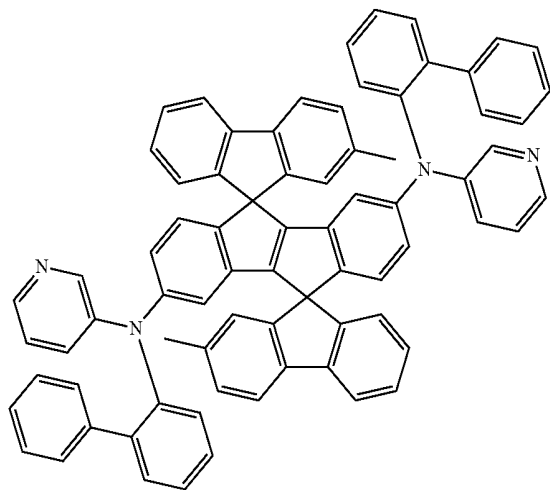
62



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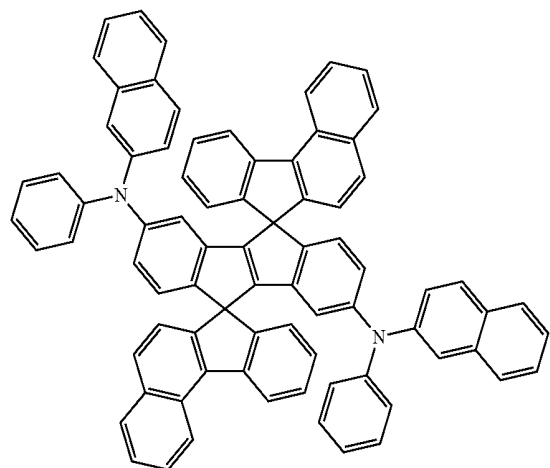
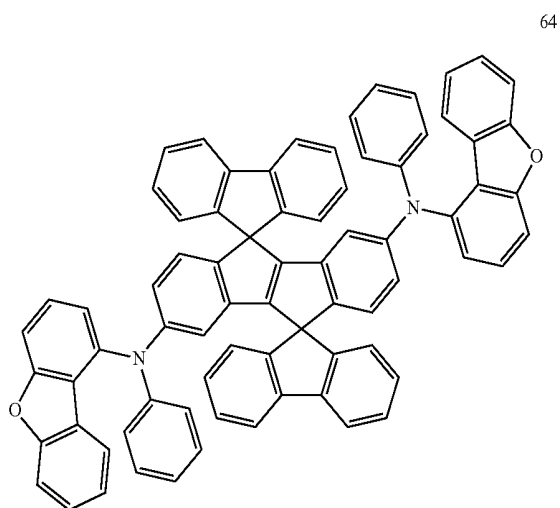


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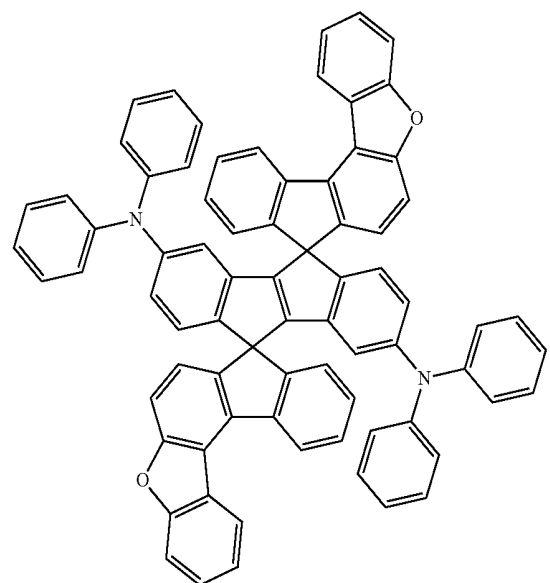
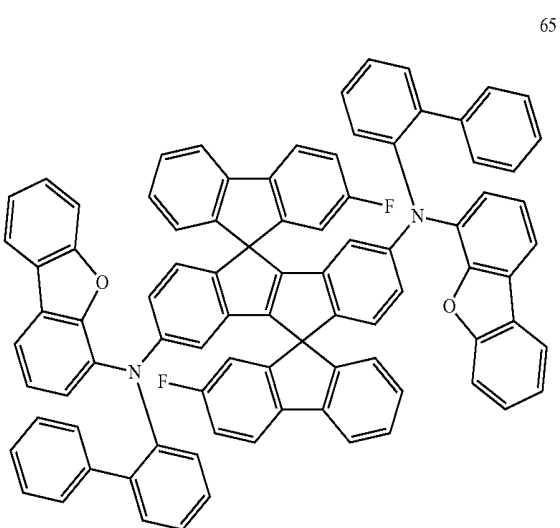


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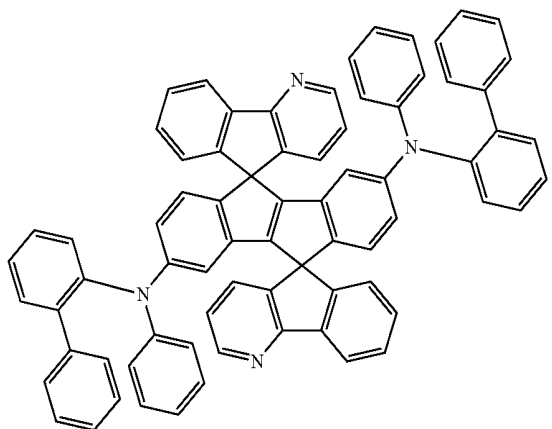


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**18.** An organic light emitting device, comprising:  
 a first electrode;  
 a second electrode facing the first electrode; and

an organic layer between the first electrode and the second electrode, the organic layer including an emission layer, wherein the organic layer includes the condensed-cyclic compound as claimed in claim 1.

**19.** The organic light-emitting device as claimed in claim 18, wherein:

the first electrode is an anode,  
 the second electrode is a cathode, and  
 the organic layer includes:

a hole transport region that is between the first electrode and the emission layer, the hole transport region including at least one selected from a hole injection layer, a hole transport layer, a buffer layer, and an electron blocking layer, and

an electron transport region that is between the emission layer and the second electrode, the electron transport region including at least one selected from a hole blocking layer, an electron transport layer, and an electron injection layer.

**20.** The organic light-emitting device as claimed in claim 19, wherein the emission layer includes a host and a dopant, and the dopant includes the condensed-cyclic compound.

\* \* \* \* \*

专利名称(译)	缩合环状化合物和包括其的有机发光器件		
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[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.		
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发明人	KIM, YOUNGKOOK KO, SOOBYUNG KIM, JONGWOO HAN, SANGHYUN HWANG, SEOKHWAN		
IPC分类号	H01L51/00 H01L51/52 C07C211/61 C07D307/91 C07F7/08 C07D213/74 C07D333/76 C07B59/00 C07D493/10 C07D495/10 C07D471/10		
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优先权	1020160104495 2016-08-17 KR		
其他公开文献	US10090474		
外部链接	<a href="#">Espacenet</a> <a href="#">USPTO</a>		

摘要(译)

缩合环状化合物和包含其的有机发光装置，该化合物由式1表示

**40**

<b>220</b>
<b>190</b>
<b>150</b>
<b>110</b>
<b>210</b>