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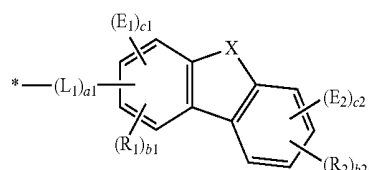
(19) **United States**(12) **Patent Application Publication** (10) **Pub. No.: US 2017/0040536 A1**
(43) **Pub. Date: Feb. 9, 2017**(54) **DIBENZOBOROLE-BASED COMPOUND AND ORGANIC LIGHT EMITTING DEVICE INCLUDING THE SAME**(57) **ABSTRACT**(71) Applicant: **SAMSUNG DISPLAY CO., LTD.**,
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A dibenzoborole-based compound and an organic light-emitting device including the same. The dibenzoborole-based compound is represented by the formula $A_1-(A_2)_{n1}$, wherein A_1 may be selected from specific aromatic and non-aromatic carbocycles and heterocycles, $n1$ may be an integer selected from 1 to 10, and each A_2 moiety may independently be selected from a group represented by Formula 2:

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Aug. 7, 2015 (KR) 10-2015-0111634

Formula 2

**Publication Classification**

- (51) **Int. Cl.**
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C07F 5/02 (2006.01)
- (52) **U.S. Cl.**
 CPC **H01L 51/008** (2013.01); **C07F 5/027**
 (2013.01); **H01L 51/5068** (2013.01)

The dibenzoborole-based compound may be included in the hole transport region or hole transport layer. When the dibenzoborole-based compound has strong electron acceptor characteristics, the hole injection barrier between the anode and the organic layer may be reduced, and thus, an organic light-emitting device including the dibenzoborole-based compound may have high efficiency and a long lifespan.

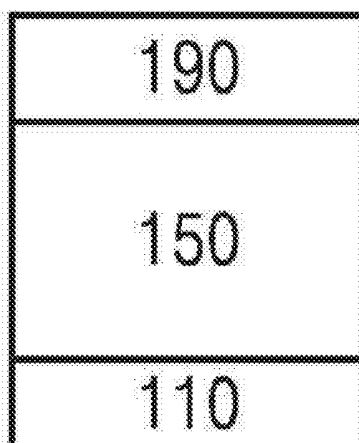
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FIG. 1

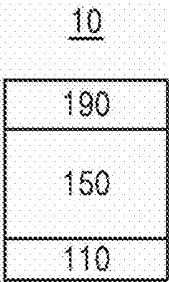


FIG. 2

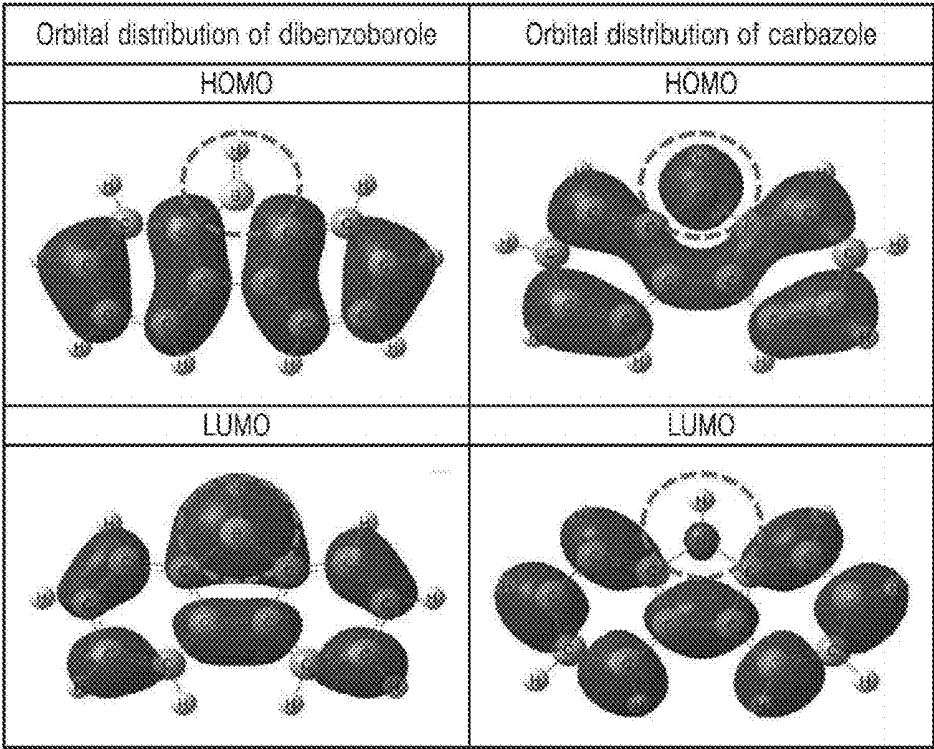
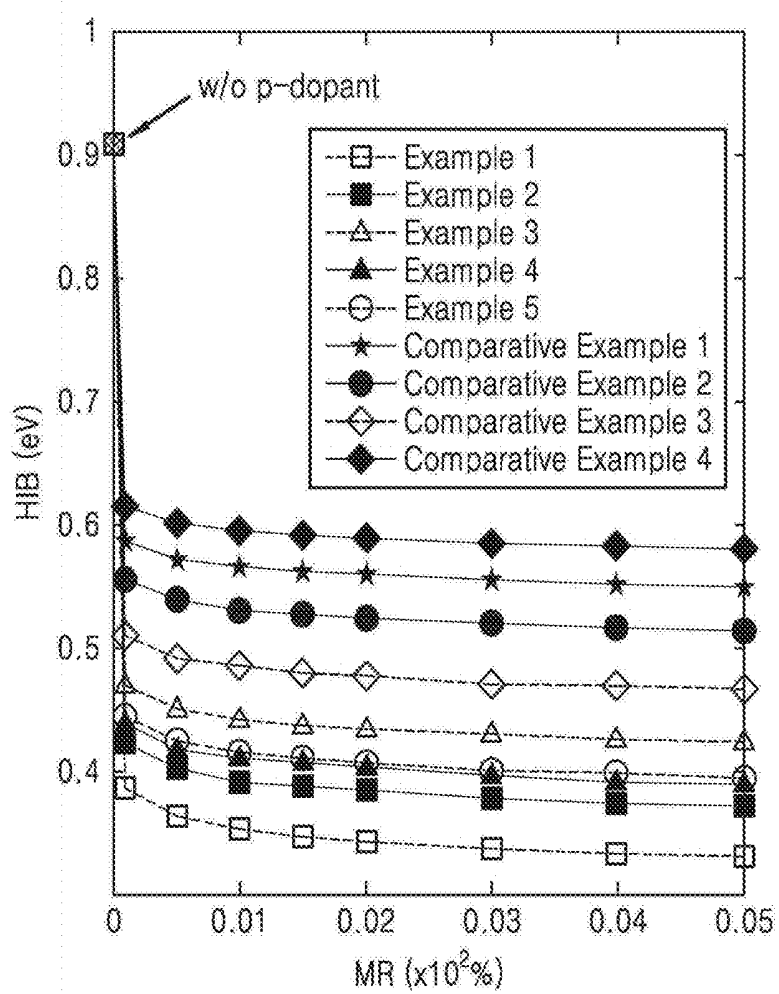


FIG. 3



DIBENZOBOROLE-BASED COMPOUND AND ORGANIC LIGHT EMITTING DEVICE INCLUDING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to and the benefit of Korean Patent Application No. 10-2015-0111634, filed on Aug. 7, 2015, in the Korean Intellectual Property Office, the entire content which is incorporated herein by reference.

BACKGROUND

[0002] 1. Field

[0003] One or more aspects of example embodiments of the present disclosure relate to a dibenzoborole-based compound and an organic light-emitting device including the same.

[0004] 2. Description of the Related Art

[0005] Organic light-emitting devices (OLEDs) are self-emission devices that have wide viewing angles, high contrast ratios, and short response times. OLEDs exhibit high luminance, driving voltage, and response speed characteristics, and may produce full-color images.

[0006] An OLED may include a first electrode on a substrate, and a hole transport region, an emission layer, an electron transport region, and a second electrode, which are sequentially positioned on the first electrode. Holes provided from the first electrode may move toward the emission layer through the hole transport region, and electrons provided from the second electrode may move toward the emission layer through the electron transport region. The holes and the electrons may recombine in the emission layer to produce excitons. These excitons may change (e.g., transition or decay) from an excited state to the ground state to thereby generate light.

SUMMARY

[0007] One or more aspects of example embodiments of the present disclosure are directed toward a dibenzoborole-based compound and an organic light-emitting device including the same.

[0008] Additional aspects will be set forth in part in the description which follows and, in part, will be apparent from the description, or may be learned by practice of the presented embodiments.

[0009] One or more example embodiments of the present disclosure provide a dibenzoborole-based compound represented by Formula 1:



Formula 1

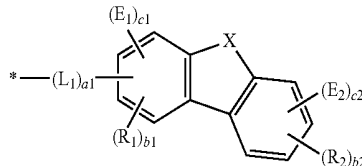
[0010] In Formula 1,

[0011] A_1 may be selected from a substituted or unsubstituted triazine, a substituted or unsubstituted vinylene carbonate, a substituted or unsubstituted thiophene, a substituted or unsubstituted azulene, a substituted or unsubstituted naphthalene, a substituted or unsubstituted anthracene, and a substituted or unsubstituted pyrene,

[0012] $n1$ may be an integer selected from 1 to 10, and when $n1$ is 2 or greater, each A_2 moiety may independently be selected from the below-described groups,

[0013] A_2 may be represented by Formula 2:

Formula 2



[0014] In Formula 2,

[0015] X may be selected from B(E_{31}) and B(R_{31}),

[0016] L_1 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,

[0017] $a1$ may be selected from 0 and 1,

[0018] E_1 , E_2 , and E_{31} may each independently be an electron withdrawing group,

[0019] $c1$ may be an integer selected from 0 to 3, $c2$ may be an integer selected from 0 to 4, and the sum of $c1$ and $c2$ may be 1 or greater,

[0020] R_1 , R_2 , and R_{31} may each independently be selected from hydrogen, deuterium, a hydroxyl group, an amino group, an imidino group, a hydrazine group, a hydrazone 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, $-N(Q_1)(Q_2)$, $-Si(Q_3)(Q_4)(Q_5)$, and $-B(Q_6)(Q_7)$,

[0021] $b1$ may be an integer selected from 0 to 3, and $b2$ may be an integer selected from 0 to 4,

[0022] at least one substituent of the substituted triazine, substituted vinylene carbonate, substituted thiophene, substituted azulene, substituted naphthalene, substituted anthracene, substituted pyrene, substituted C_3 - C_{10} cycloalkylene group, substituted C_1 - C_{10} heterocycloalkylene group, substituted C_3 - C_{10} cycloalkenylene group, substituted C_1 - C_{10} heterocycloalkenylene group, substituted C_6 - C_{60} arylene group, substituted C_1 - C_{60} heteroarylene group, substituted divalent non-aromatic condensed polycyclic group, substituted divalent non-aromatic condensed heteropolycyclic group, substituted C_1 - C_{60} alkyl group, substituted C_2 - C_{60} alkenyl group, substituted C_2 - C_{60} alkynyl group, substituted C_1 - C_{60} alkoxy group, substituted C_3 - C_{10} cycloalkyl group, substituted C_1 - C_{10} heterocycloalkyl group, substituted C_3 - C_{10} cycloalkenyl group, substituted C_1 - C_{10} heterocycloalkenyl group, substituted C_6 - C_{60} aryl group, substituted

C₆-C₆₀ aryloxy group, substituted C₆-C₆₀ arylthio group, substituted C₁-C₆₀ heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from:

[0023] deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group;

[0024] a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q₁₁)(Q₁₂), —Si(Q₁₃)(Q₁₄)(Q₁₅), and —B(Q₁₆)(Q₁₇),

[0025] a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

[0026] a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q₂₁)(Q₂₂), —Si(Q₂₃)(Q₂₄)(Q₂₅), and —B(Q₂₆)(Q₂₇), and

[0027] —N(Q₃₁)(Q₃₂), —Si(Q₃₃)(Q₃₄)(Q₃₅), and —B(Q₃₆)(Q₃₇),

[0028] wherein Q₁ to Q₇, Q₁₁ to Q₁₇, Q₂₁ to Q₂₇, and Q₃₁ to Q₃₇ may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group,

a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, and * may indicate a binding site to A₁.

BRIEF DESCRIPTION OF THE DRAWINGS

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

[0030] FIG. 1 is a schematic cross-sectional view of an embodiment of an organic light-emitting device;

[0031] FIG. 2 is a series of images showing the HOMO and LUMO molecular orbital probability distributions of a dibenzoborole and a carbazole; and

[0032] FIG. 3 is a graph showing the energy level of a hole injection barrier (HIB) at the interface between the anode and the hole transport layer as a function of the molar ratio (MR) of p-dopant to matrix material. In the graphed samples, the matrix is HT21, and the p-dopants are selected from the compounds of Examples 1 to 5 and Comparative Examples 1 to 4.

DETAILED DESCRIPTION

[0033] Reference will now be made in more detail to example embodiments, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout and duplicative descriptions thereof will not be provided. In this regard, the present example embodiments may have different forms and should not be construed as being limited to the descriptions set forth herein. Accordingly, the example embodiments are merely described below, by referring to the drawings, to explain aspects of the present description. As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items. Expressions such as “at least one of”, “one of”, “at least one selected from”, and “one selected from” when preceding a list of elements, modify the entire list of elements and do not modify the individual elements of the list.

[0034] In the drawings, the thickness of layers, films, panels, regions, etc., may be exaggerated for clarity. It will be understood that when an element such as a layer, film, region, or substrate is referred to as being “on” another element, it can be directly on the other element or intervening element(s) may also be present. In contrast, when an element is referred to as being “directly on” another element, no intervening elements are present.

[0035] One or more aspects of embodiments of the present disclosure provide a dibenzoborole-based compound represented by Formula 1:

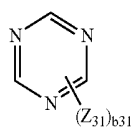


Formula 1

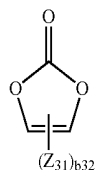
[0036] In Formula 1,

[0037] A₁ may be selected from a substituted or unsubstituted triazine, a substituted or unsubstituted vinylene carbonate, a substituted or unsubstituted thiophene, a substituted or unsubstituted azulene, a substituted or unsubstituted naphthalene, a substituted or unsubstituted anthracene, and a substituted or unsubstituted pyrene.

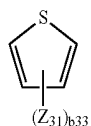
[0038] In some embodiments, in Formula 1, A₁ may be selected from Formulae 1A to 7A:



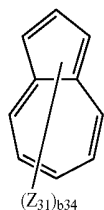
1A



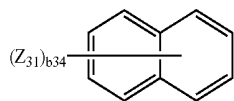
2A



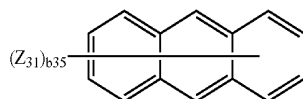
3A



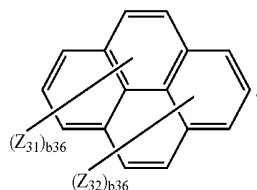
4A



5A



6A



7A

[0039] In Formulae 1A to 7A,

[0040] Z₃₁ and Z₃₂ may each independently be selected from:

[0041] a binding site to A₂;

[0042] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group;

[0043] a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q₁₁)(Q₁₂), —Si(Q₁₃)(Q₁₄)(Q₁₆), and —B(Q₁₆)(Q₁₇),

[0044] a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q₁₁)(Q₁₂), —Si(Q₁₃)(Q₁₄)(Q₁₆), and —B(Q₁₆)(Q₁₇),

[0045] a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

[0046] —N(Q₃₁)(Q₃₂), —Si(Q₃₃)(Q₃₄)(Q₃₅), and —B(Q₃₆)(Q₃₇),

[0047] wherein Q₁₁ to Q₁₇, Q₂₁ to Q₂₇, and Q₃₁ to Q₃₇ may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q₂₁)(Q₂₂), —Si(Q₂₃)(Q₂₄)(Q₂₆), and —B(Q₂₆)(Q₂₇), and

[0048] the number of Z₃₁ substituents and/or the number Z₃₁ and Z₃₂ substituents that are binding sites to A₂ may each be n1,

[0049] b31 may be an integer selected from 1 to 3,

[0050] b32 may be an integer selected from 1 and 2,

[0051] b33 may be an integer selected from 1 to 4,

[0052] b34 may be an integer selected from 1 to 8,

[0053] b35 may be an integer selected from 1 to 10, and

[0054] b36 may be an integer selected from 1 to 5.

[0055] In Formulae 1A to 7A, Z_{31} and Z_{32} may each independently be selected from:

[0056] hydrogen, deuterium, a hydroxyl group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

[0057] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group; and

[0058] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group, each substituted with at least one selected from deuterium, a hydroxyl group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and $-\text{Si}(\text{Q}_{33})(\text{Q}_{34})(\text{Q}_{35})$, wherein Q_{33} to Q_{35} may be the same as described earlier herein.

[0059] In some embodiments, in Formulae 1A to 7A, Z_{31} and Z_{32} may each independently be selected from:

[0060] hydrogen, deuterium, a hydroxyl group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

[0061] a phenyl group and a naphthyl group; and

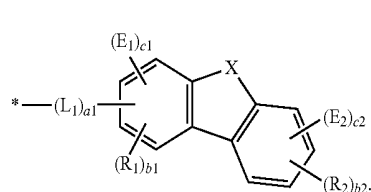
[0062] a phenyl group and a naphthyl group, each substituted with at least one selected from deuterium, a hydroxyl group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, and a naphthyl group, but embodiments of the present disclosure are not limited thereto.

[0063] In Formula 1, n_1 indicates the number of A_2 moieties, wherein n_1 may be an integer selected from 1 to 10. When n_1 is an integer of 2 or greater, each A_2 moiety may be independently selected from the below-described groups.

[0064] In some embodiments, in Formula 1, n_1 may be an integer selected from 1 to 8.

[0065] In some embodiments, in Formula 1, n_1 may be an integer selected from 1 to 6.

[0066] In Formula 1, A_2 may be a group represented by Formula 2:



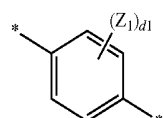
Formula 2

[0067] In Formula 2, X may be selected from $B(E_{31})$ and $B(R_{31})$. E_{31} and R_{31} may be the same as described earlier herein.

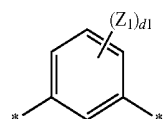
[0068] In some embodiments, in Formula 2, X may be $B(E_{31})$.

[0069] In Formula 2, L_1 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.

[0070] In some embodiments, in Formula 2, L_1 may be selected from groups represented by Formulae 3-1 to 3-11:

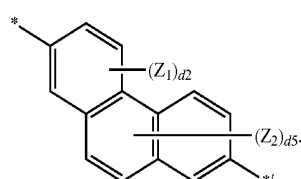
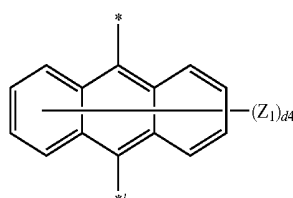
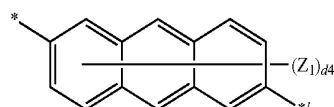
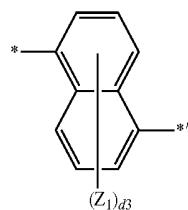
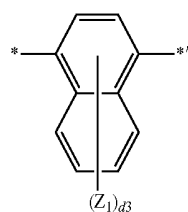
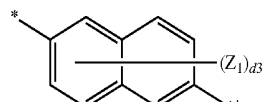
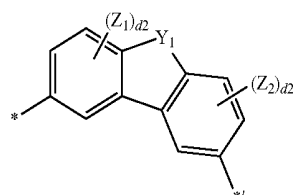
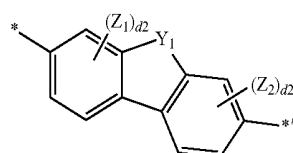
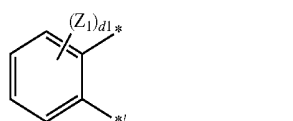


3-1



3-2

-continued



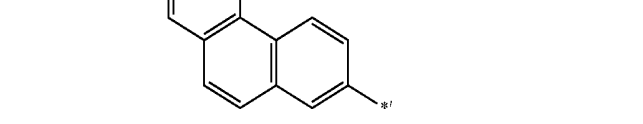
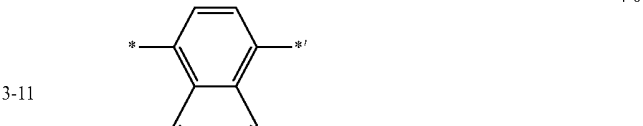
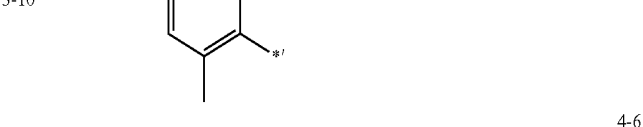
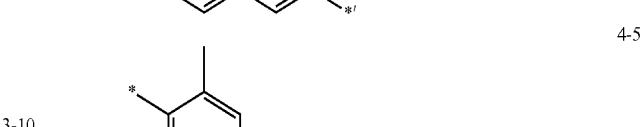
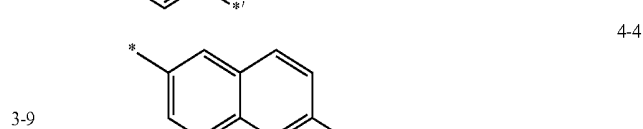
[0071] In Formulae 3-1 to 3-11,

[0072] Y_1 may be $C(Z_3)(Z_4)$,

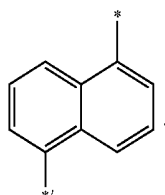
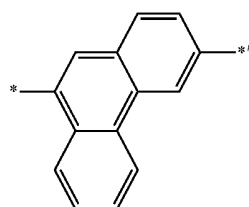
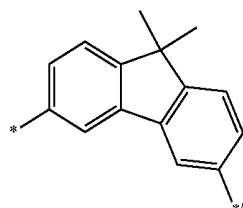
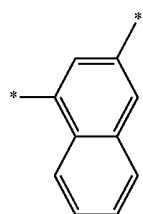
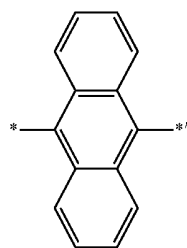
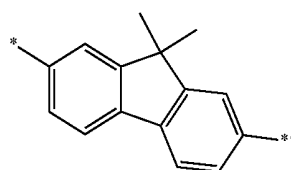
[0073] Z_1 to Z_4 may each independently be selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, and a chrysenyl group,

[0074] d_1 may be an integer selected from 1 to 4, d_2 may be an integer selected from 1 to 3, d_3 may be an integer selected from 1 to 6, d_4 may be an integer selected from 1 to 8, d_5 may be an integer selected from 1 to 5; and $*$ and $*'$ may each indicate a binding site to an adjacent atom.

[0075] In some embodiments, in Formula 2, L_1 may be selected from groups represented by Formulae 4-1 to 4-13, but embodiments of the present disclosure are not limited thereto:



-continued



[0076] In Formulae 4-1 to 4-13, * and *¹ may each indicate a binding site to an adjacent atom.

[0077] In Formula 2, a₁ indicates the number of L₁ moieties, wherein, in Formula 2, a₁ may be 0 or 1. When a₁ is 0, *-(L₁)_{a1}-*¹ indicates a single bond (e.g., a direct linkage).

[0078] In some embodiments, in Formula 2, a₁ may be 0.

[0079] In Formula 2, E₁, E₂, and E₃₁ may each independently be an electron withdrawing group.

[0080] In some embodiments, in Formula 2, E₁, E₂, and E₃₁ may each independently be selected from —F, —Cl,

—Br, —I, —CN, —NO₂, —CF₃, —CCl₃, —C₂F₃, —C₂Cl₃, —C₂(CN)₃, —CBr₃, —C(NO₂)₃, —C₂Br₃, —C₂I₃, —C₂(NO₂)₃, and —PO(Ph)₃.

[0081] In some embodiments, in Formula 2, E₁, E₂, and E₃₁ may each independently be selected from —CN, —CF₃, —CCl₃, —C₂F₃, —C₂Cl₃, —C₂(CN)₃, —CBr₃, —C(NO₂)₃, —C₂Br₃, —C₂I₃, and —C₂(NO₂)₃, but embodiments of the present disclosure are not limited thereto.

[0082] In Formula 2, c₁ indicates the number of E₁ moieties, and c₂ indicates the number of E₂ moieties. c₁ may be an integer selected from 0 to 3, c₂ may be an integer selected from 0 to 4, and the sum of c₁ and c₂ may be 1 or greater. When c₁ is 2 or greater, each E₁ moiety may independently be selected from the earlier described groups. When c₂ is 2 or greater, each E₂ moiety may independently be selected from the earlier described groups.

[0083] In some embodiments, in Formula 2, X may be B(E₃₁), and

[0084] the sum of c₁ and c₂ may be 4 or greater.

[0085] In some embodiments, in Formula 2, X may be B(E₃₁),

[0086] c₁ may be 2, and c₂ may be 2, but embodiments of the present disclosure are not limited thereto.

[0087] In Formula 2, R₁, R₂, and R₃₁ may each independently be selected from hydrogen, deuterium, a hydroxyl group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₂-C₆₀ alkenyl group, a substituted or unsubstituted C₂-C₆₀ alkynyl group, a substituted or unsubstituted C₁-C₆₀ alkoxy group, a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —N(Q₁)(Q₂), —Si(Q₃)(Q₄)(Q₅), and —B(Q₆)(Q₇).

[0088] Q₁ to Q₇ may be the same as described herein in connection with Q₁₁.

[0089] In Formula 2, R₁, R₂, and R₃₁ may each independently be selected from hydrogen, deuterium, a hydroxyl group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a C₁-C₂₀ alkyl group, and a C₁-C₂₀ alkoxy group;

[0090] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a benzimidazolyl group, a benzofuranyl group, a benzothio-phenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, an oxadiazolyl group, a

triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group; and

[0091] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group, each substituted with at least one selected from deuterium, a hydroxyl group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and $-\text{Si}(\text{Q}_{33})(\text{Q}_{34})(\text{Q}_{35})$, wherein Q_{33} to Q_{35} may be the same as described earlier herein.

[0092] In some embodiments, in Formula 2, R_1 , R_2 , and R_{31} may each independently be selected from:

[0093] hydrogen, deuterium, a hydroxyl group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

[0094] a phenyl group and a naphthyl group; and

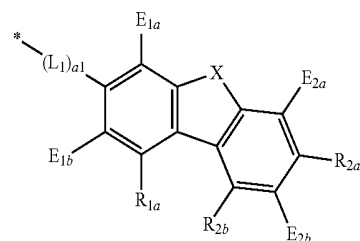
[0095] a phenyl group and a naphthyl group, each substituted with at least one selected from deuterium, a hydroxyl group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, and a naphthyl group.

[0096] In some embodiments, in Formula 2, R_1 and R_2 may be hydrogen.

[0097] In Formula 2, b_1 indicates the number of R_1 moieties, and b_2 indicates the number of R_2 moieties. b_1 may be an integer selected from 0 to 3, and b_2 may be an integer selected from 0 to 4.

[0098] In some embodiments, in Formula 2, b_1 and b_2 may be 0, but embodiments of the present disclosure are not limited thereto.

[0099] In Formula 1, A_2 may be further represented by Formula 2A:



Formula 2A

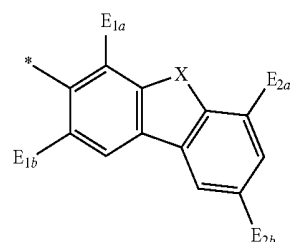
[0100] In Formula 2A, X, L_1 , and a_1 may be the same as described earlier herein, E_{1a} and E_{1b} may be the same as described earlier herein in connection with E_1 , E_{2a} and E_{2b} may be the same as described earlier herein in connection with E_2 , R_{1a} may be the same as described earlier herein in connection with R_1 , and R_{2a} and R_{2b} may be the same as described earlier herein in connection with R_2 .

[0101] In some embodiments, in Formula 2A, X may be $\text{B}(\text{E}_{31})$,

[0102] a_1 may be 0, and

[0103] R_{1a} , R_{2a} , and R_{2b} may be hydrogen.

[0104] In Formula 1, A_2 may be further represented by Formula 2A(1):

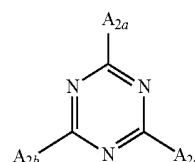


Formula 2A(1)

[0105] In Formula 2A(1), X, E_{1a} , E_{1b} , E_{2a} , and E_{2b} may be the same as defined earlier herein.

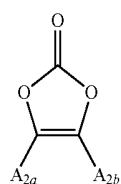
[0106] In some embodiments, in Formula 2A(1), X may be $\text{B}(\text{E}_{31})$.

[0107] According to an embodiment of the present disclosure, the dibenzoborole-based compound may be represented by one selected from Formulae 1-1 to 1-7:

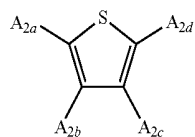


1-1

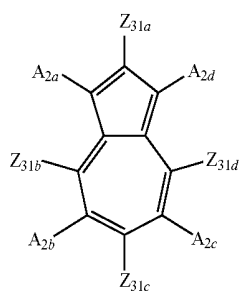
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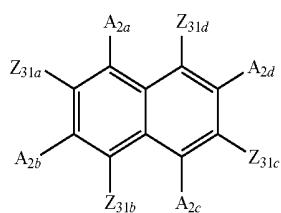
1-2



1-3

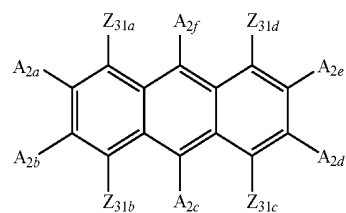


1-4

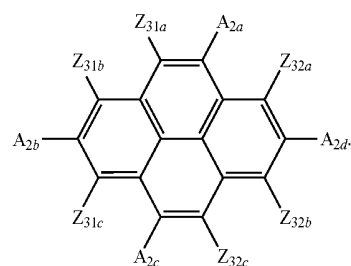


1-5

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1-6

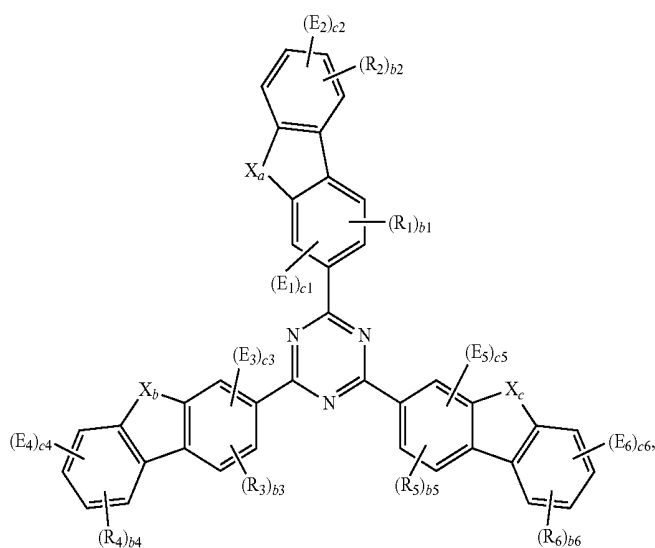


1-7

[0108] In Formulae 1-1 to 1-7, A_{2a} to A_{2f} may be the same as described herein in connection with A_2 , Z_{31a} to Z_{31d} may be the same as described herein in connection with Z_{31} , and Z_{32a} to Z_{32c} may be the same as described herein in connection with Z_{32} .

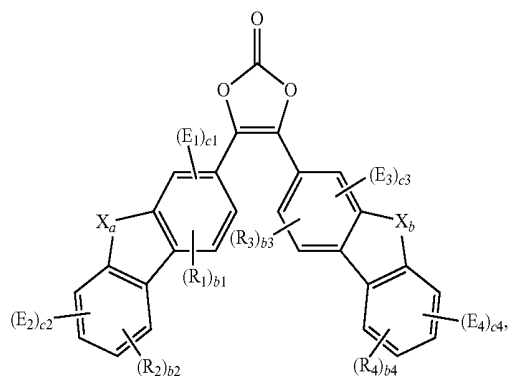
[0109] In some embodiments, the dibenzoborole-based compound may be further represented by one selected from Formulae 1-1(1) to 1-7(1):

Formula 1-1(1)

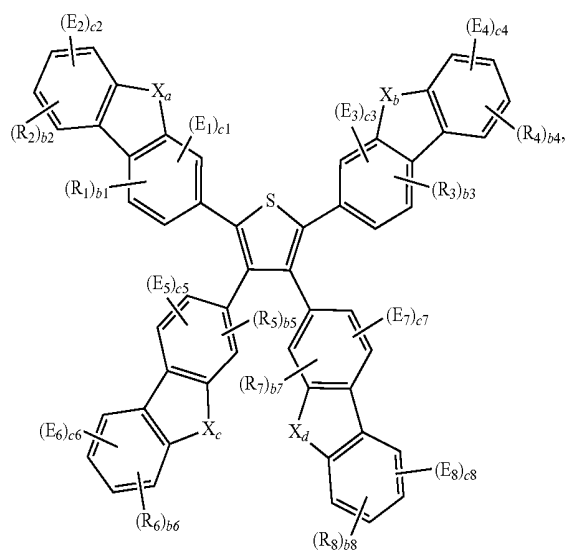


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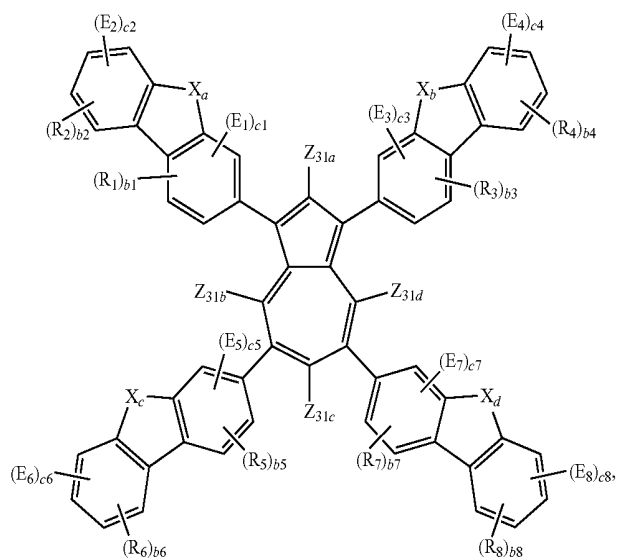
Formula 1-2(1)



Formula 1-3(1)

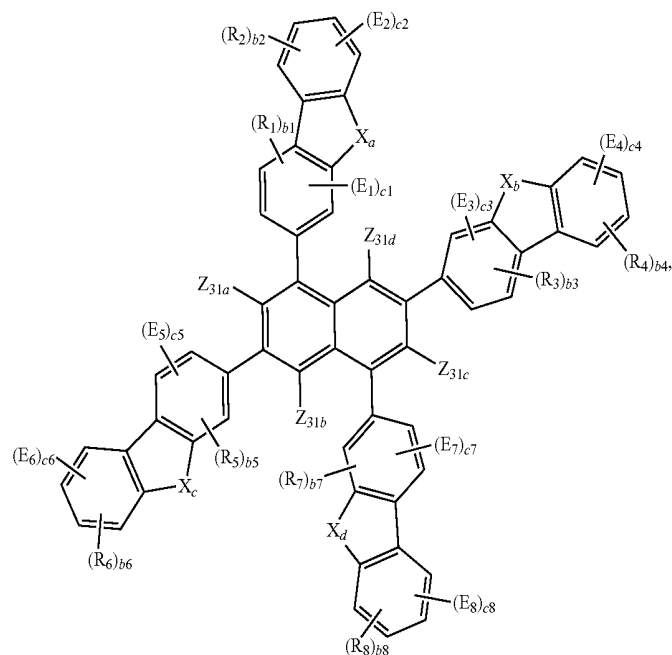


Formula 1-4(1)

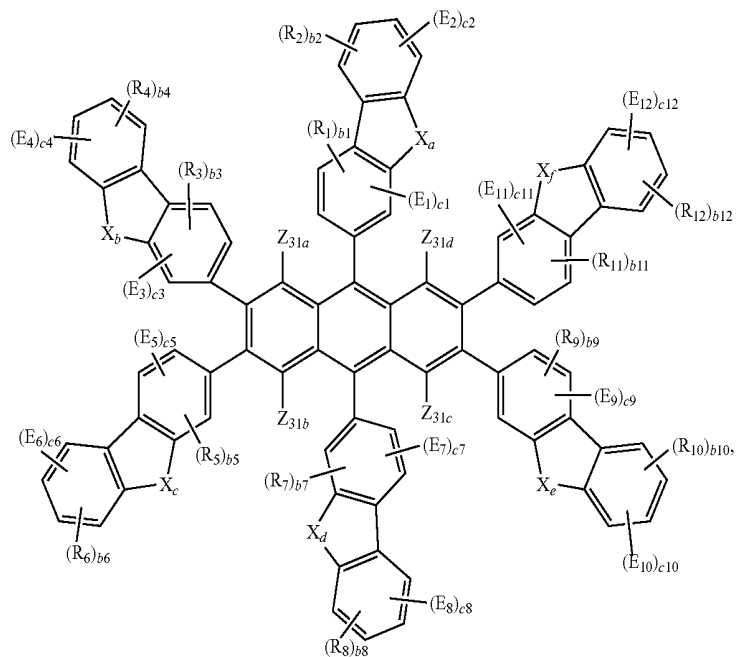


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Formula 1-5(1)

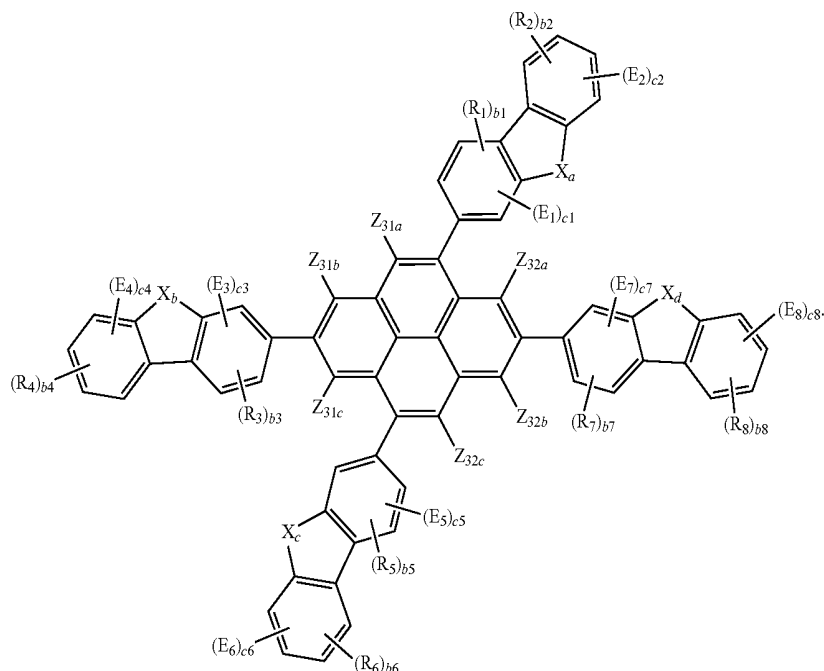


Formula 1-6(1)



-continued

Formula 1-7(1)



[0110] In Formulae 1-1(1) to 1-7(1),

[0111] E_1 , E_2 , C_1 , c_2 , R_1 , R_2 , b_1 , b_2 , Z_{31a} to Z_{31d} , and Z_{32a} to Z_{32c} may be the same as described earlier herein,

[0112] E_3 , E_5 , E_7 , E_9 , and E_{11} may be the same as described herein in connection with E_1 ,

[0113] E_4 , E_6 , E_8 , E_{10} , and E_{12} may be the same as described herein in connection with E_{27}

[0114] c_3 , c_5 , c_7 , c_9 , and c_{11} may be the same as described herein in connection with c_1 ,

[0115] c_4 , c_6 , c_8 , c_{10} , and c_{12} may be the same as described herein in connection with c_2 ,

[0116] R_3 , R_5 , R_7 , R_9 , and R_{11} may be the same as described herein in connection with R_1 ,

[0117] R_4 , R_6 , R_8 , R_{10} , and R_{12} may be the same as described herein in connection with R_2 ,

[0118] b_3 , b_5 , b_7 , b_9 , and b_{11} may be the same as described herein in connection with b_1 ,

[0119] b_4 , b_6 , b_8 , b_{10} , and b_{12} may be the same as described herein in connection with b_2 ,

[0120] X_a may be selected from $B(E_{31a})$ and $B(R_{31a})$,

[0121] X_b may be selected from $B(E_{31b})$ and $B(R_{31b})$,

[0122] X_c may be selected from $B(E_{31c})$ and $B(R_{31c})$,

[0123] X_d may be selected from $B(E_{31d})$ and $B(R_{31d})$,

[0124] X_e may be selected from $B(E_{31e})$ and $B(R_{31e})$,

[0125] X_f may be selected from $B(E_{31f})$ and $B(R_{31f})$,

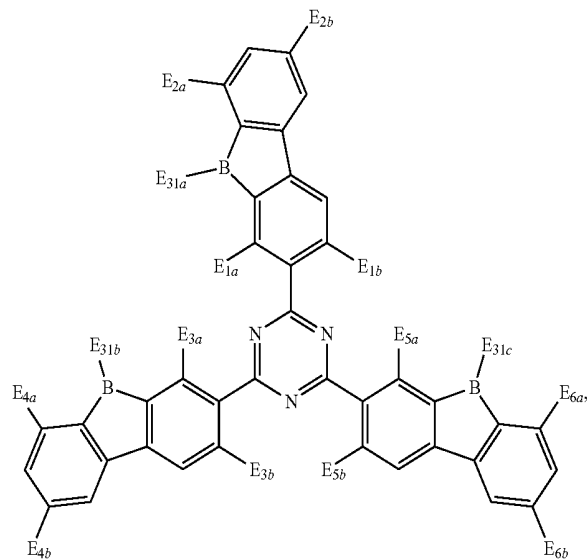
[0126] E_{31a} to E_{31f} may be the same as described herein in connection with E_{31} , and R_{31a} to R_{31f} may be the same as described herein in connection with R_{31} .

[0127] In some embodiments, in Formulae 1-1(1) to 1-7(1),

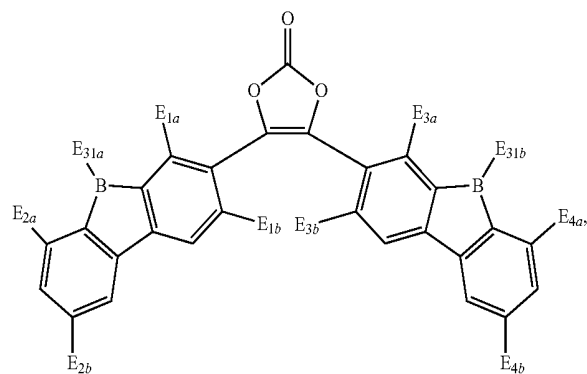
[0128] X_a may be $B(E_{31a})$, X_b may be $B(E_{31b})$, X_c may be $B(E_{31c})$, X_d may be $B(E_{31d})$, X_e may be $B(E_{31e})$, and X_f may be $B(E_{31f})$.

[0129] In some embodiments, the dibenzoborole-based compound may be further represented by one selected from Formulae 1-1(1)1 to 1-7(1)1:

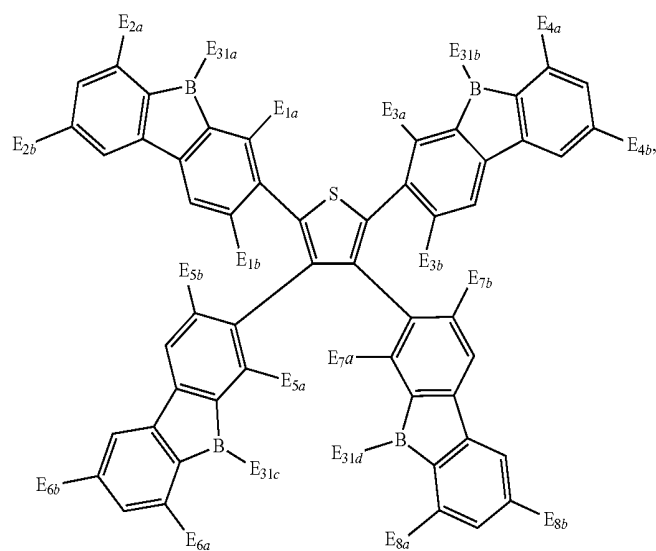
Formula 1-1(1)1



Formula 1-2(1)1

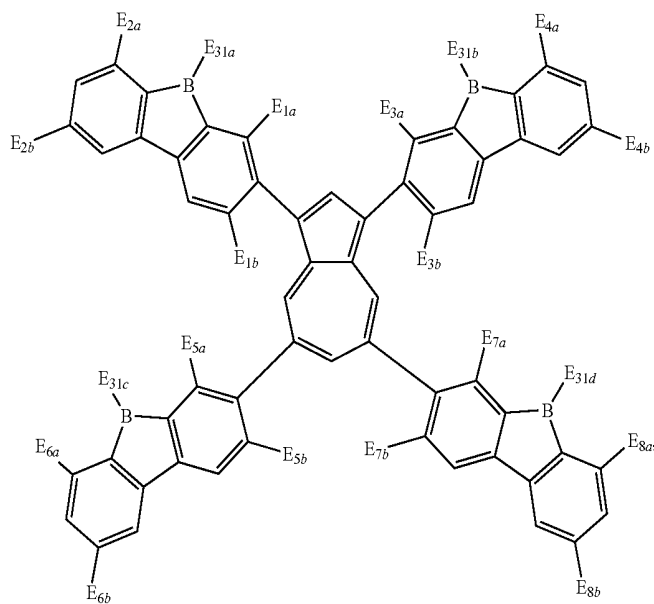


Formula 1-3(1)1

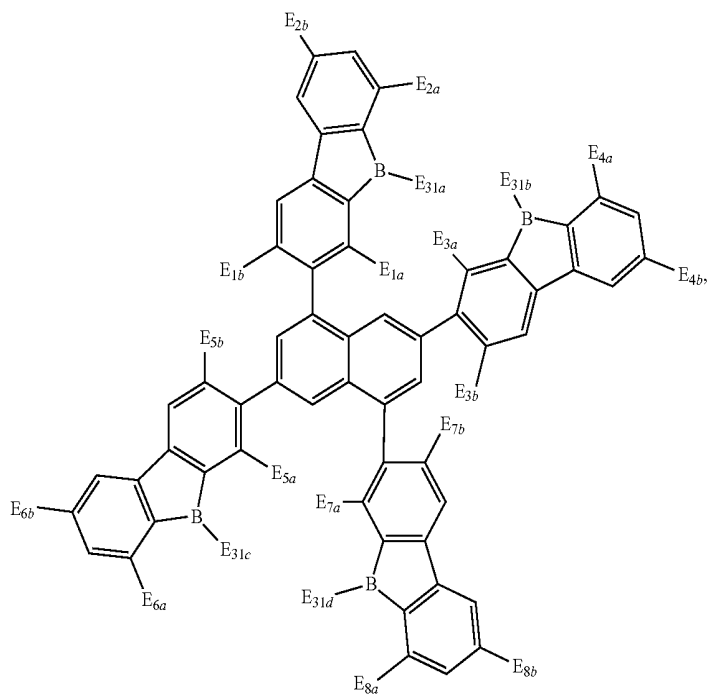


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Formula 1-4(1)1

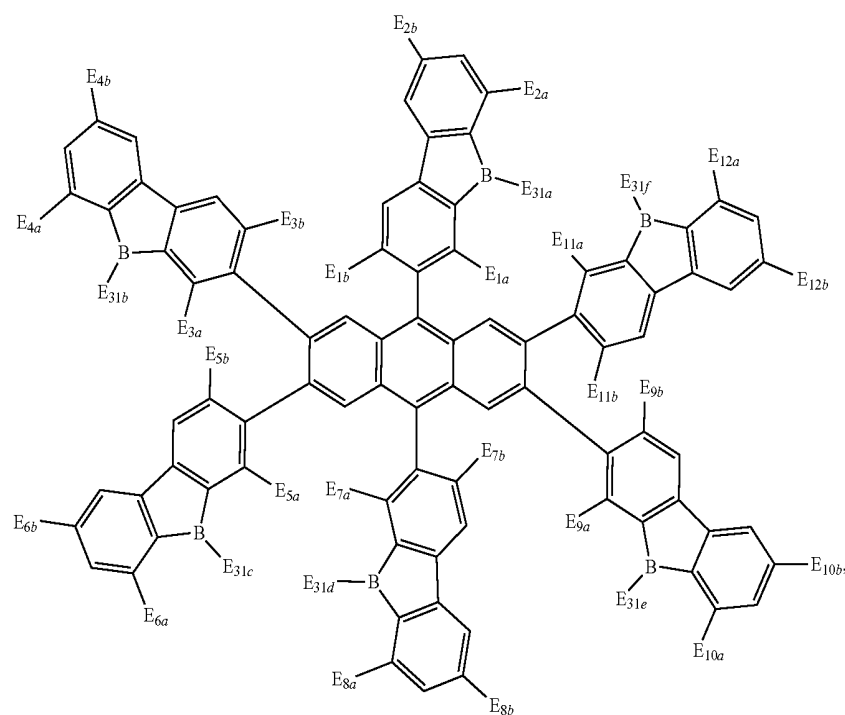


Formula 1-5(1)1

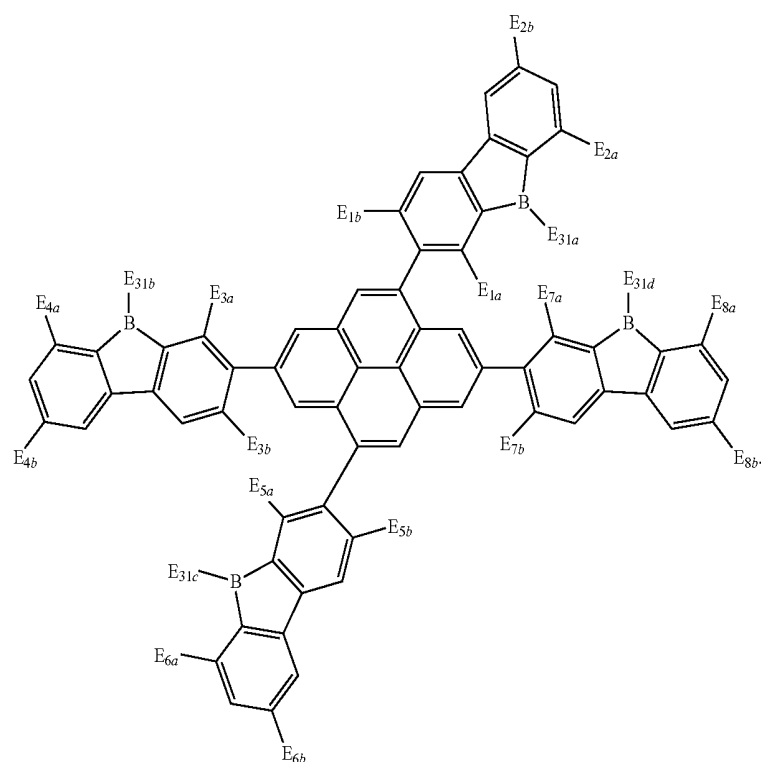


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Formula 1-6(1)1



Formula 1-7(1)1

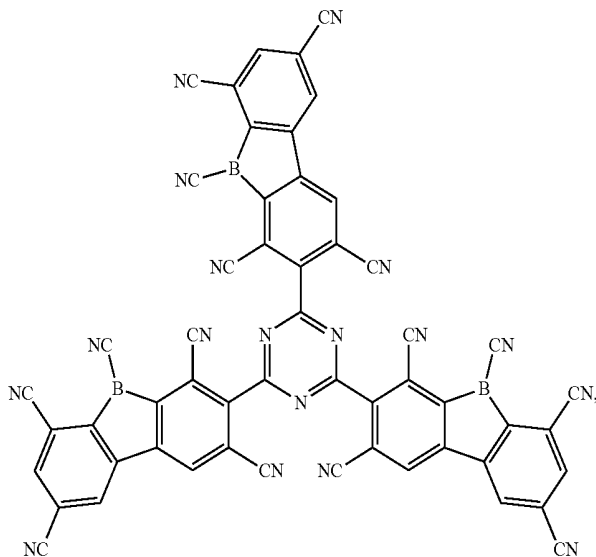


[0130] In Formulae 1-1(1)1 to 1-7(1)1,

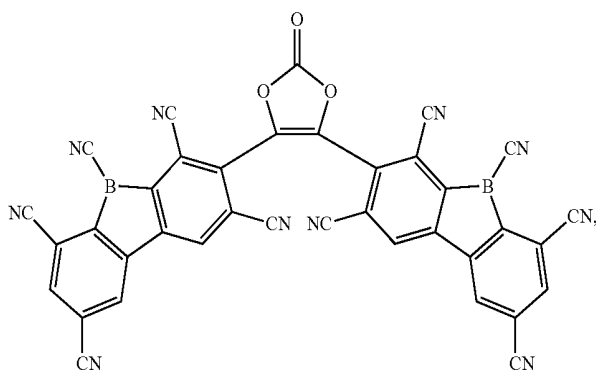
[0131] E_{1a} , E_{1b} , E_{3a} , E_{3b} , E_{5a} , E_{5b} , E_{7a} , E_{7b} , E_{9a} , E_{9b} , E_{11a} , and E_{11b} may be the same as described herein in connection with E_1 ;

[0134] In some embodiments, the dibenzoborole-based compound may be selected from Compounds 1 to 7, but embodiments of the present disclosure are not limited thereto:

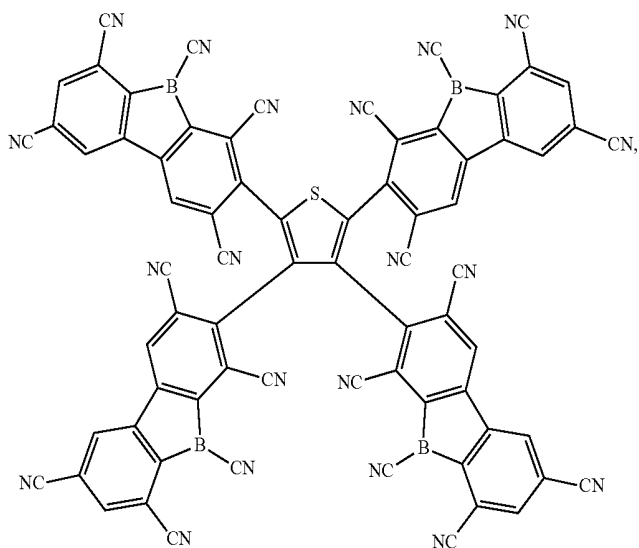
Compound 1



Compound 2

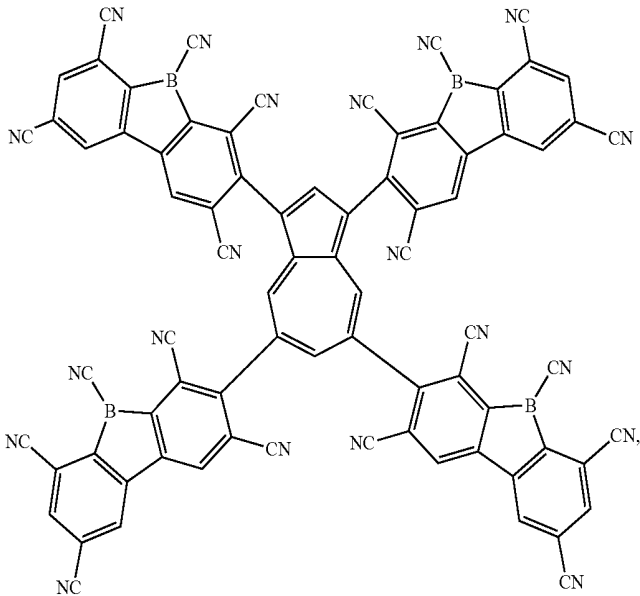


Compound 3

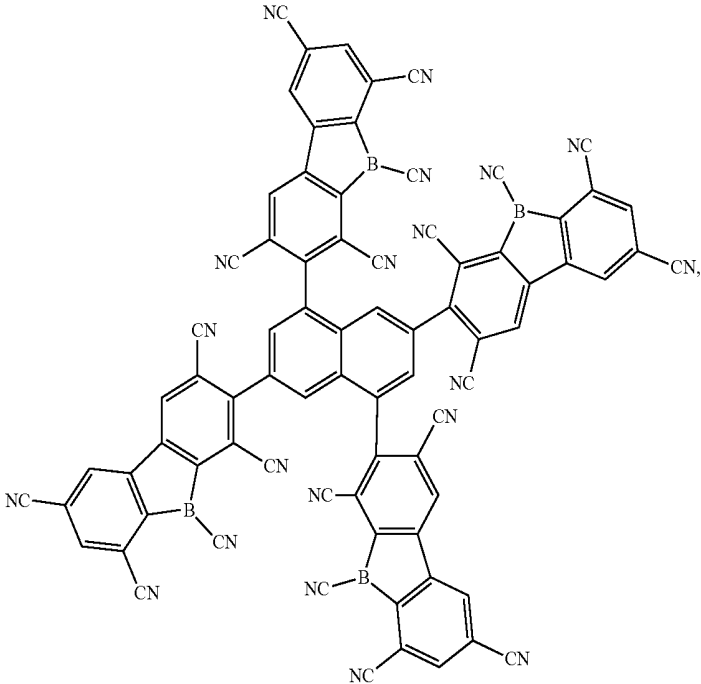


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Compound 4

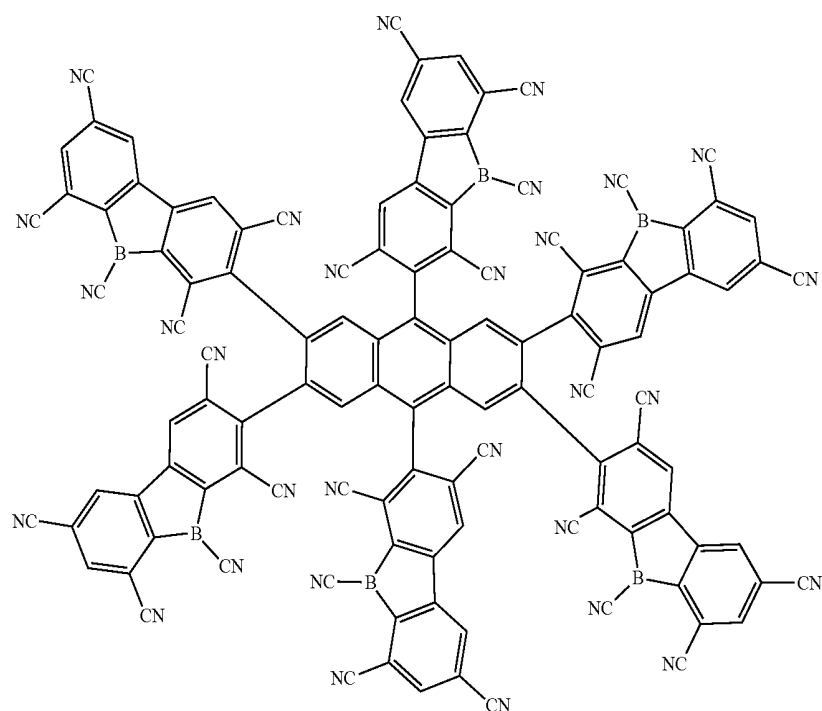


Compound 5

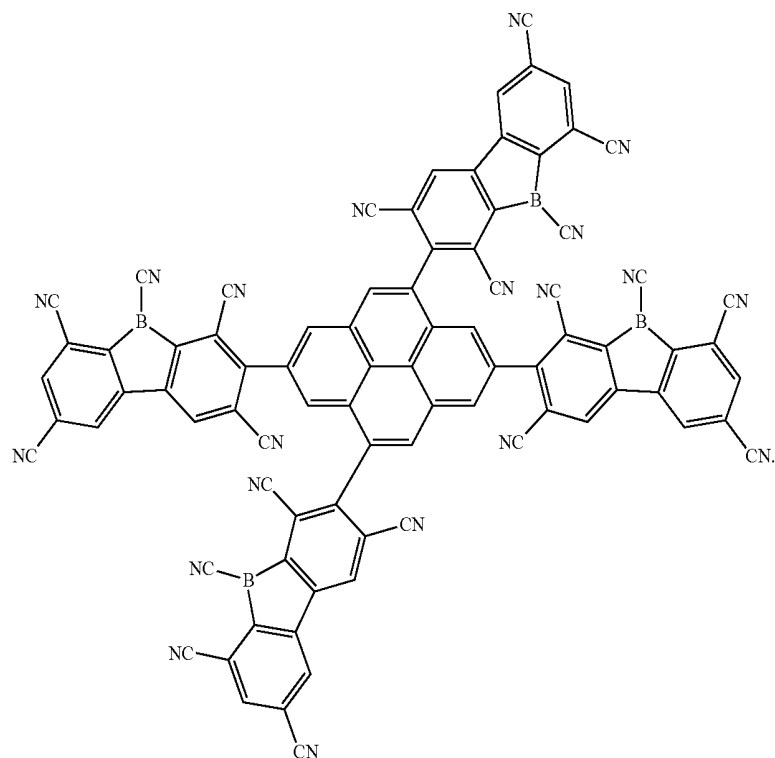


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Compound 6



Compound 7



[0135] A_2 represented by Formula 2 may include a dibenzoborole structure having an electron withdrawing group.

[0136] FIG. 2 is a series of images comparing the highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO) molecular orbital distributions (e.g., electron density probabilities) of a dibenzoborole

(where the ring-forming heteroatom is boron (B)) with those of a carbazole (where the ring-forming heteroatom is nitrogen (N)).

[0137] Referring to FIG. 2, the B atom in the dibenzoborole may have a small orbital distribution area of the highest occupied molecular orbital (HOMO) (e.g., the B

atom contributes a small amount of electron density to the HOMO), and a large orbital distribution area of the lowest unoccupied molecular orbital (LUMO) (e.g., the B atom contributes a large amount of electron density to the LUMO). This suggests that the dibenzoborole B atom may have strong electron acceptor characteristics. In contrast, the N atom in the carbazole may have a large orbital distribution area of HOMO, and a small orbital distribution area of LUMO (e.g., the N atom contributes a large amount of electron density to the HOMO and a small amount to the LUMO). This suggests that the carbazole N atom may have electron donor characteristics. Accordingly, it was found that dibenzoborole, which is an example of A_2 represented by Formula 2, has good electron acceptor characteristics compared to carbazole.

[0138] In some embodiments, simulated using the Vienna ab initio simulation package (VASP), the difference in electron affinity between a dibenzoborole and a carbazole may be about 1.5 eV.

[0139] For a dibenzoborole to have more (e.g., stronger) electron acceptor characteristics, a dibenzoborole may be symmetrically substituted with an electron withdrawing group, for example, a cyano group ($-\text{CN}$), in which the electron withdrawing group is positioned where the LUMO orbital distribution area in the molecular orbital distribution of the dibenzoborole is large (e.g., in regions of high electron density).

[0140] In some embodiments, electron withdrawing group having a carbon atom, (e.g., $-\text{CN}$, $-\text{CF}_3$, $-\text{CCl}_3$, $-\text{C}_2\text{Cl}_5$, and $-\text{C}_2(\text{CN})_3$), may form a carbon-carbon bond with the dibenzoborole, granting a high binding energy (e.g., forming a strong bond) with a dibenzoborole-based compound.

[0141] Therefore, the dibenzoborole-based compound represented by Formula 1 according to an embodiment of the present disclosure may have a structure in which an A_2 including a strong electron withdrawing group is substituted (e.g., coupled) to an A_1 core having strong electron acceptor characteristics, and may thereby have a high electron affinity value.

[0142] The dibenzoborole-based compound represented by Formula 1 may have an electron affinity of about 4.5 eV to about 5.0 eV, and in some examples, about 4.6 eV to about 4.95 eV. When the electron affinity of the dibenzoborole-based compound represented by Formula 1 is within these ranges, the hole injection barrier at the interface between an anode and an organic layer may be reduced, and thus, an organic light-emitting device including the dibenzoborole-based compound may have high efficiency and a long lifespan.

[0143] The dibenzoborole-based compound represented by Formula 1 may be used in a pair of electrodes in an organic light-emitting device. For example, the dibenzoborole-based compound may be included in a hole transport region, and for example, in a hole transport layer. Accordingly, an organic light-emitting device may include: a first electrode; a second electrode facing the first electrode; and an organic layer between the first electrode and the second electrode and including an emission layer, wherein the organic layer may include the dibenzoborole-based compound represented by Formula 1.

[0144] As used herein, the expression “the (organic layer) includes at least one dibenzoborole-based compound” may refer to “the (organic layer) may include one dibenzoborole-

based compound represented by Formula 1 or two different dibenzoborole-based compounds represented by Formula 1”.

[0145] For example, the organic layer may include only Compound 1 as the dibenzoborole-based compound. In this regard, Compound 1 may be included in the hole transport layer of the organic light-emitting device. In some embodiments, the organic layer may include Compound 1 and Compound 2 as the dibenzoborole-based compounds. In this regard, Compound 1 and Compound 2 may be present in the same layer (for example, both Compound 1 and Compound 2 may be situated in a hole transport layer), and/or in different layers (for example, Compound 1 may be present in a hole transport layer and Compound 2 may be present in a hole injection layer).

[0146] The organic layer may include i) a hole transport region between the first electrode (anode) and the emission layer that includes at least one selected from a hole injection layer, a hole transport layer, a buffer layer, and an electron blocking layer, and ii) an electron transport region between the emission layer and the second electrode (cathode) that includes at least one selected from a hole blocking layer, an electron transport layer, and an electron injection layer. The hole transport layer may include the dibenzoborole-based compound represented by Formula 1.

[0147] As used herein, the term “organic layer” may refer to a single layer and/or a plurality of layers between the first electrode and the second electrode in an organic light-emitting device. A material included in the “organic layer” may include other materials besides an organic material.

[0148] FIG. 1 illustrates a schematic view of an organic light-emitting device 10 according to an embodiment of the present disclosure. The organic light-emitting device 10 may include a first electrode 110, an organic layer 150, and a second electrode 190.

[0149] Hereinafter, a structure and a method of manufacturing an organic light-emitting device according to an embodiment of the present disclosure will be described with reference to FIG. 1.

[0150] Referring to FIG. 1, a substrate may be under the first electrode 110 or on the second electrode 190. The substrate may be a glass substrate and/or a transparent plastic substrate, each with excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and/or water resistance.

[0151] The first electrode 110 may be formed by depositing and/or sputtering a material for forming the first electrode 110 on the substrate. When the first electrode 110 is an anode, the material for the first electrode 110 may be selected from materials with a high work function that facilitate hole injection. The first electrode 110 may be a reflective electrode, a semi-transmissive electrode, and/or a transmissive electrode. The material for the first electrode 110 may be a transparent and highly conductive material. Non-limiting examples of such a material may include indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO_2), and/or zinc oxide (ZnO). When the first electrode 110 is a semi-transmissive electrode or a reflective electrode,

as a material for forming the first electrode **110**, at least one selected from magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), and magnesium-silver (Mg—Ag) may be used.

[0152] The first electrode **110** may have a single-layer structure, and/or a multi-layer structure including a plurality of layers. For example, the first electrode **110** may have a triple-layer structure of ITO/Ag/ITO, but embodiments of the present disclosure are not limited thereto.

[0153] The organic layer **150** may be on the first electrode **110**. The organic layer **150** may include an emission layer.

[0154] The organic layer **150** may further include a hole transport region between the first electrode **110** and the emission layer and/or an electron transport region between the emission layer and the second electrode **190**.

[0155] The hole transport region may include at least one selected from a hole injection layer, a hole transport layer, a buffer layer, and an electron blocking layer, and the electron transport region may include at least one selected from a hole blocking layer, an electron transport layer, and an electron injection layer, but embodiments of the present disclosure are not limited thereto.

[0156] The hole transport region may have a single-layered structure including a single material, a single-layered structure including a plurality of different materials, and/or a multi-layered structure having a plurality of layers including a plurality of different materials.

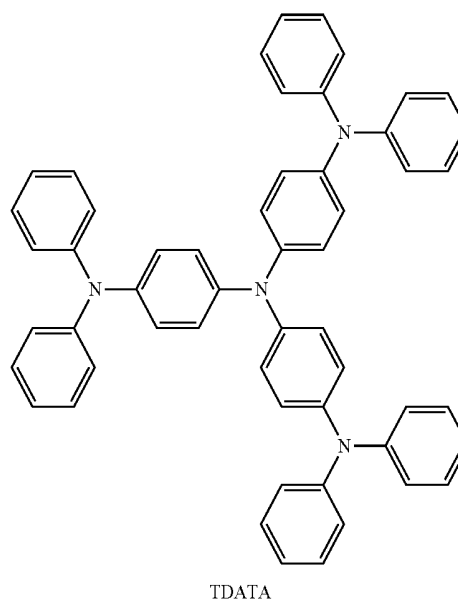
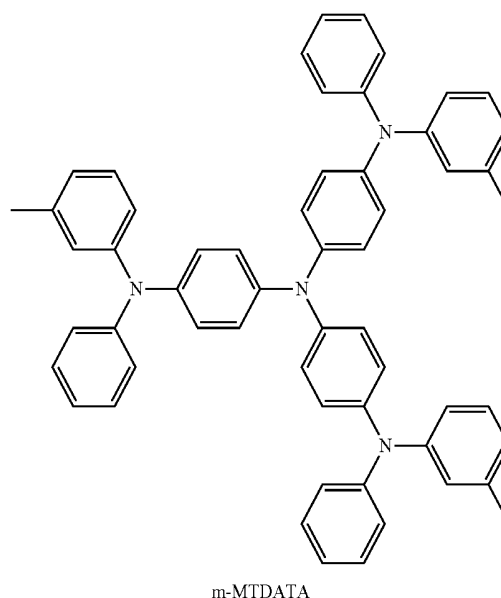
[0157] For example, the hole transport region may have a single-layered structure formed of a plurality of different materials, a structure of hole injection layer/hole transport layer, a structure of hole injection layer/hole transport layer/buffer layer, a structure of hole injection layer/buffer layer, a structure of hole transport layer/buffer layer, and/or a structure of hole injection layer/hole transport layer/electron blocking layer, wherein layers of each structure are sequentially stacked from the first electrode **110** in the stated order, but embodiments of the present disclosure are not limited thereto.

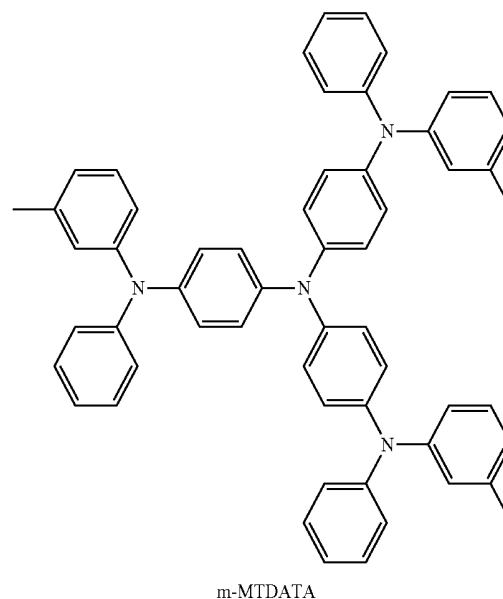
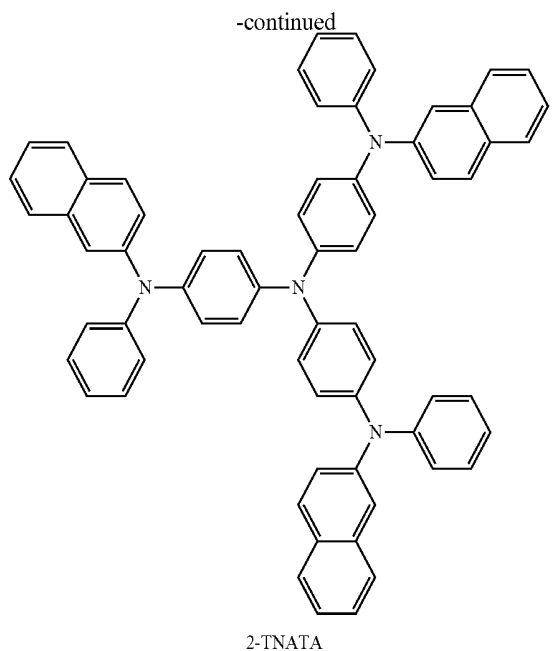
[0158] When the hole transport region includes a hole injection layer, the hole injection layer may be formed on the first electrode **110** using one or more suitable methods, such as vacuum deposition, spin coating, casting, a Langmuir-Blodgett (LB) method, ink-jet printing, laser printing, and/or LITI.

[0159] When a hole injection layer is formed by vacuum deposition, for example, the vacuum deposition may be performed at a deposition temperature of about 100 to about 500° C., at a vacuum degree of about 10^{-8} to about 10^{-3} torr, and at a deposition rate of about 0.01 to about 100 Å/sec, depending on the compound to be deposited, and the structure to be formed.

[0160] When a hole injection layer is formed by spin coating, the spin coating may be performed at a coating rate of about 2000 rpm to about 5000 rpm and at a temperature of about 80° C. to 200° C., depending on the compound to be deposited, and the structure to be formed.

[0161] Any suitable hole injection material may be used, for example, DNTPD (N,N'-diphenyl-N,N'-bis-[4-(phenyl-m-tolyl-amino)-phenyl]-biphenyl-4,4'-diamine), a phthalocyanine compound such as copper phthalocyanine, m-MT-DATA [4,4',4''-tris (3-methylphenylphenylamino) triphenylamine], NPB (N,N'-di(1-naphthyl)-N,N'-diphenylbenzidine), TDATA, 2-TNATA, PANI/DBSA (polyaniline/dodecylbenzenesulfonic acid), PEDOT/PSS (poly(3,4-ethylenedioxythiophene)/Poly(4-styrenesulfonate)), PANI/CSA (polyaniline/camphor sulfonic acid), or PANI/PSS (polyaniline/poly(4-styrenesulfonate)), but embodiments of the present disclosure are not limited thereto:





[0162] In some embodiments, the hole injection layer may include the dibenzoborole-based compound represented by Formula 1, but embodiments of the present disclosure are not limited thereto.

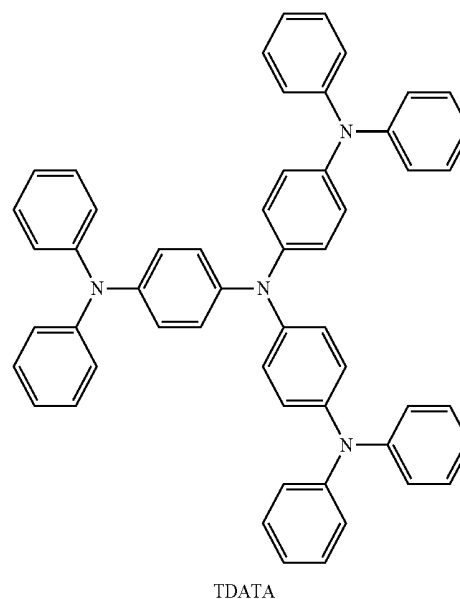
[0163] The hole transport layer may be formed on the first electrode 110 or on the hole injection layer using one or more suitable methods, such as vacuum deposition, spin coating, casting, an LB method, ink-jet printing, laser-printing, and/or LITI. When the hole transport layer is formed by vacuum deposition and/or spin coating, the vacuum deposition and coating conditions may be similar to the vacuum deposition and coating conditions used to form the hole injection layer.

[0164] The hole transport layer may include the dibenzoborole-based compound represented by Formula 1.

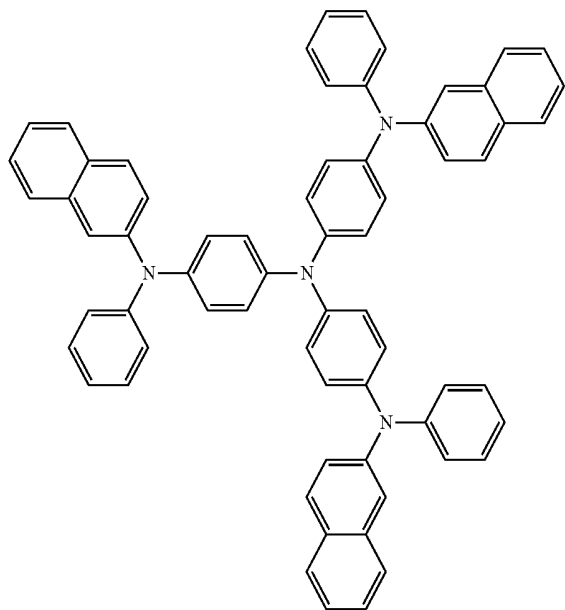
[0165] In some embodiments, the dibenzoborole-based compound represented by Formula 1 may be a p-dopant.

[0166] The hole transport layer may include a matrix material as well as the dibenzoborole-based compound represented by Formula 1.

[0167] The matrix material may be at least one selected from m-MTDATA, TDATA, 2-TNATA, NPB, β -NPB, TPD, a spiro-TPD, a spiro-NPB, methylated NPB, TAPC, HMTDPD, 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 below, and a compound represented by Formula 202 below:

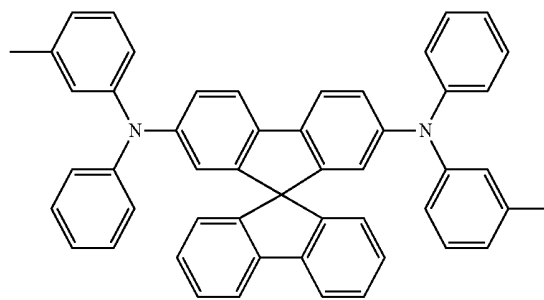


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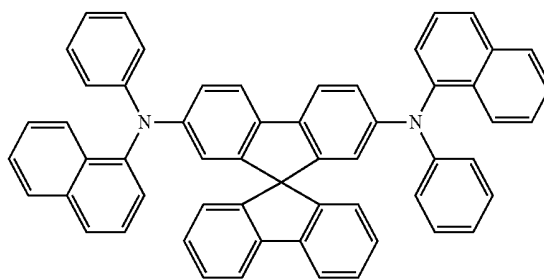


2-TNATA

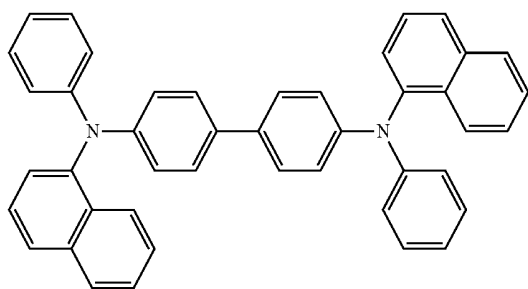
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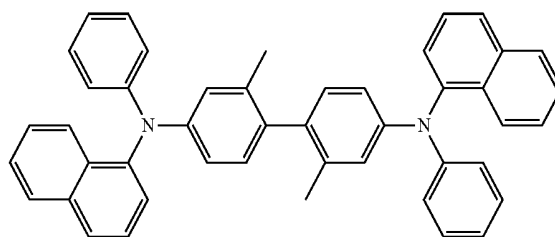
Spiro-TPD



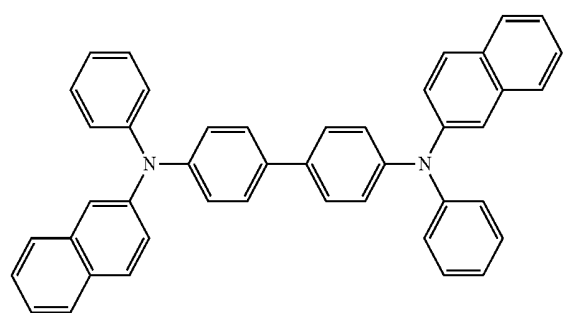
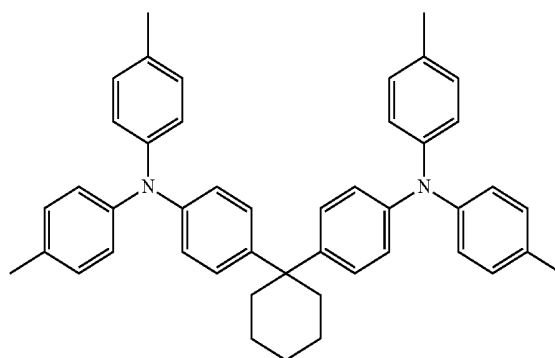
Spiro-NPB



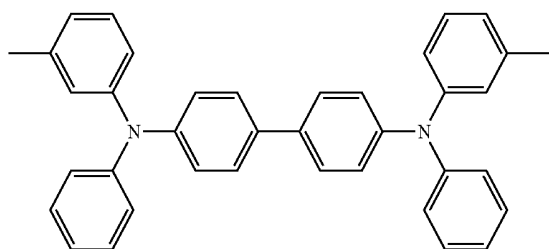
NPB



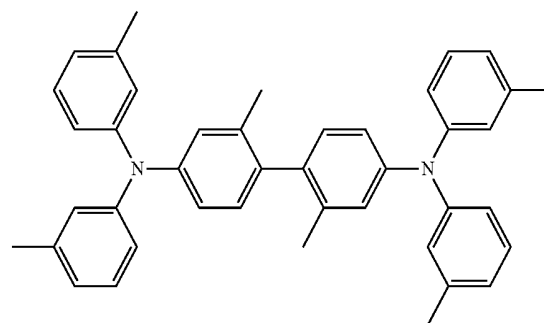
methylated NPB

 β -NPB

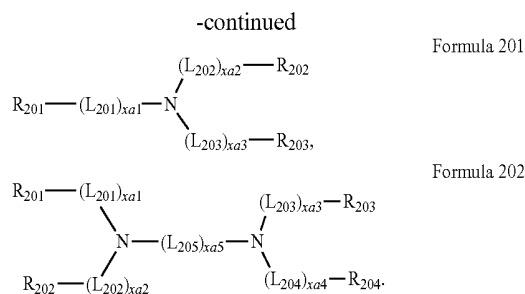
TAPC



TPD



HMTPD



[0168] In Formulae 201 and 202,

[0169] L_{201} to L_{205} may be the same as described herein in connection with L_1 ;

[0170] xa1 to xa4 may each independently be an integer selected from 0, 1, 2, and 3; and

[0171] xa5 may be selected from 1, 2, 3, 4, and 5, and

[0172] R_{201} to R_{204} 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.

[0173] In some embodiments, in Formulae 201 and 202,

[0174] L_{201} to L_{204} may each independently be selected from:

[0175] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorene group, a dibenzofluorene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, a chrysenylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a quinolinylene group, an isoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a carbazolyne group, and a triazinylene group; and

[0176] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, a chrysenylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a quinolinylene group, an isoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a carbazolyne group, and a triazinylene 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 amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group,

a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group,

[0177] xa1 to xa4 may each be an integer independently selected from 0, 1, and 2,

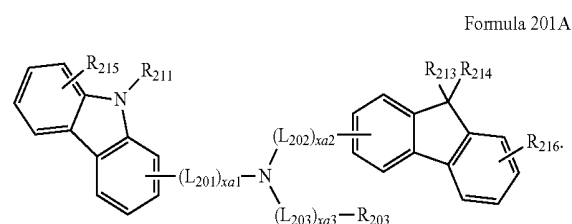
[0178] xa5 may be selected from 1, 2, and 3,

[0179] R_{201} to R_{204} may each independently be selected from:

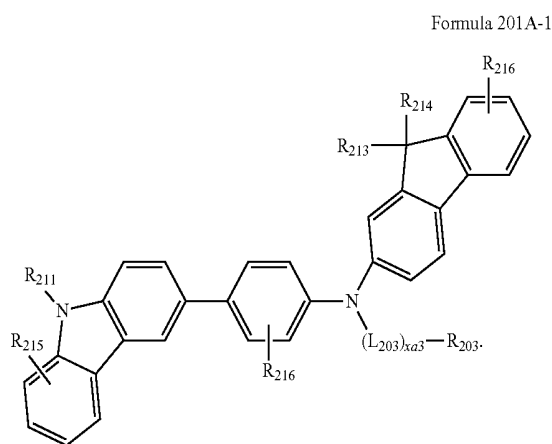
[0180] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

[0181] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl 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 amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, an azulenyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, but embodiments of the present disclosure are not limited thereto.

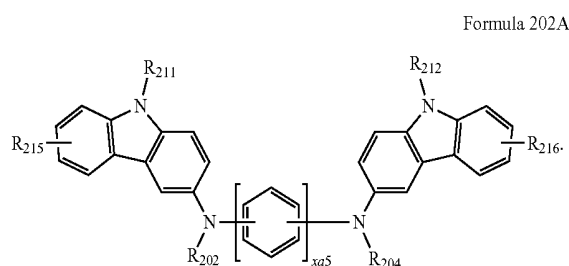
[0182] The compound represented by Formula 201 may be further represented by Formula 201A:



[0183] In some embodiments, the compound represented by Formula 201 may be further represented by Formula 201A-1, but embodiments of the present disclosure are not limited thereto:



[0184] In some embodiments, the compound represented by Formula 202 may be further represented by Formula 202A, but embodiments of the present disclosure are not limited thereto:



[0185] In Formulae 201A, 201A-1, and 202A, L_{201} to L_{203} , $xa1$ to $xa3$, $xa5$, and R_{202} to R_{204} may be the same as defined earlier herein, R_{211} and R_{212} may each independently be the same as defined herein in connection with R_{203} , and R_{213} to R_{216} may each independently be selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

[0186] In some embodiments, in Formulae 201A, 201A-1, and 202A,

[0187] L_{201} to L_{203} may each independently be selected from:

[0188] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylenylene group, a pyrenylene group, a chrysenylene group, a pyridinylenylene group, a pyrazinylenylene group, a pyrimidinylenylene group, a pyridazinylene group, a

quinolinylene group, an isoquinolinylene group, a quinoxalinylenylene group, a quinazolinylene group, a carbazolylene group, and a triazinylene group; and

[0189] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylenylene group, a pyrenylene group, a chrysenylene group, a pyridinylenylene group, a pyrazinylenylene group, a pyrimidinylenylene group, a pyridazinylene group, a quinolinylene group, an isoquinolinylene group, a quinoxalinylenylene group, a quinazolinylene group, a carbazolylene group, and a triazinylene group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group,

[0190] $xa1$ to $xa3$ may each independently be selected from 0 and 1,

[0191] R_{202} to R_{204} , R_{211} , and R_{212} may each independently be selected from:

[0192] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

[0193] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group,

[0194] R_{213} and R_{214} may each independently be selected from:

[0195] a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group;

[0196] a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

[0197] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

[0198] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group,

[0199] R_{215} and R_{216} may each independently be selected from:

[0200] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic

acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, and a C_1 - C_{20} alkoxy group;

[0201] a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

[0202] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, and a triazinyl group; and

[0203] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, and

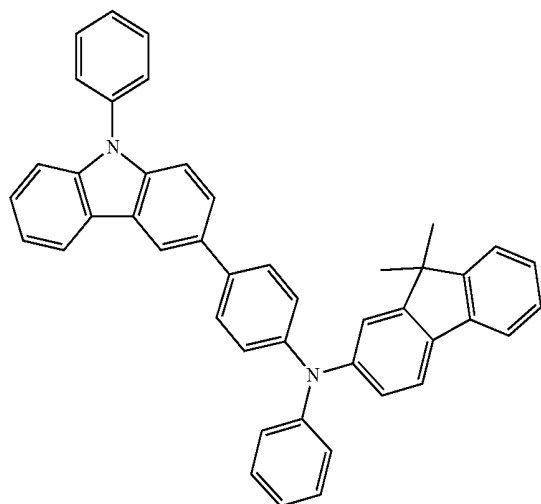
[0204] $xa5$ may be selected from 1 and 2.

[0205] In Formulae 201A and 201A-1, R_{213} and R_{214} may be bound (e.g., coupled) to each other to form a saturated ring or an unsaturated ring.

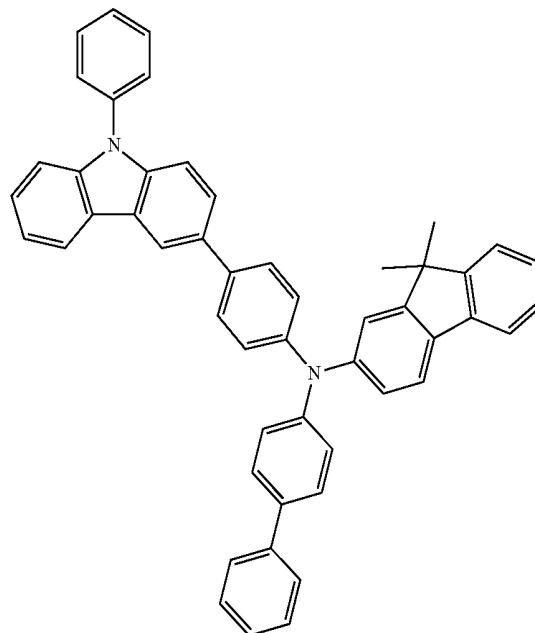
[0206] The compound represented by Formula 201 and the compound represented by Formula 202 may include Compounds HT1 to HT20 and HT21, but embodiments of the present disclosure are not limited thereto:

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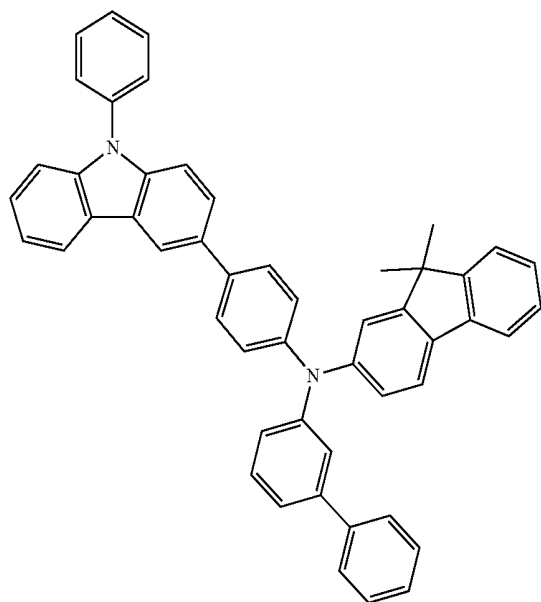
HT1



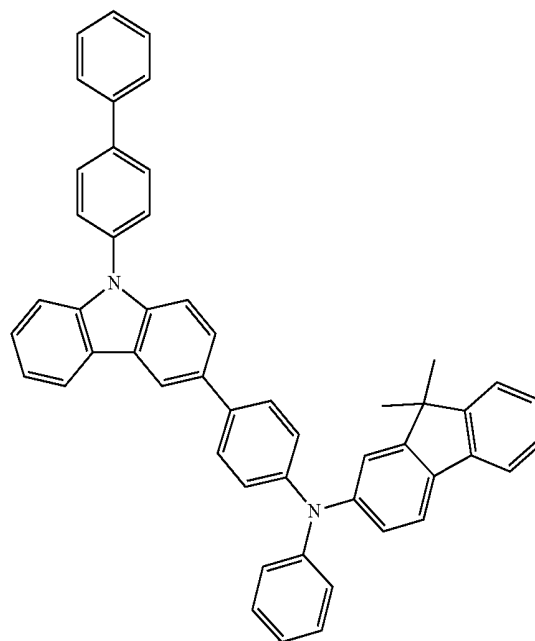
HT3



HT2

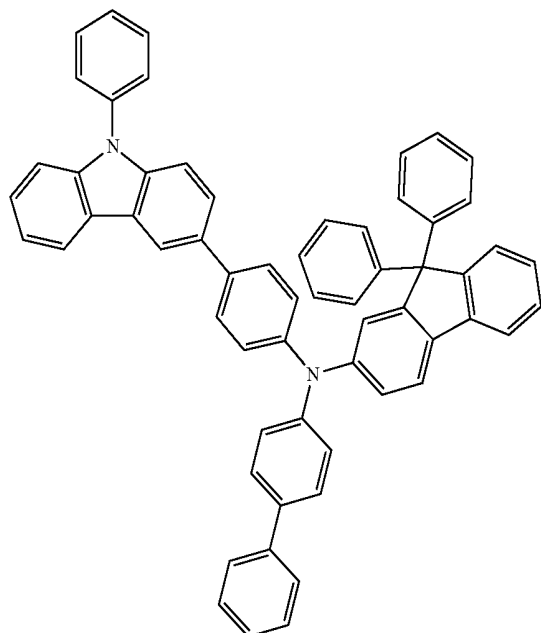


HT4



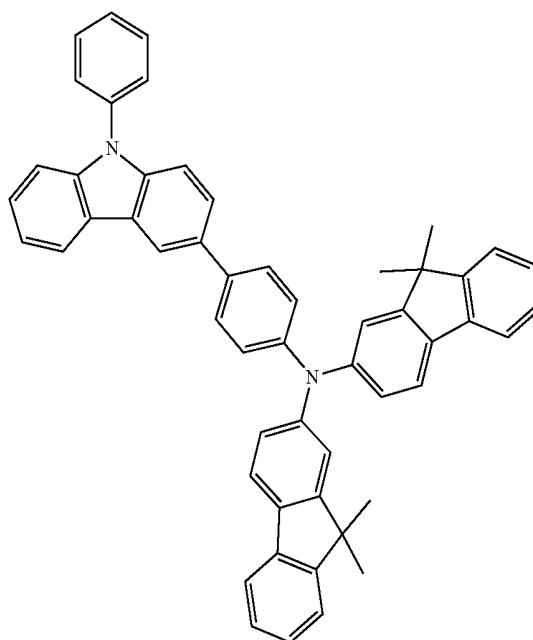
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HT5

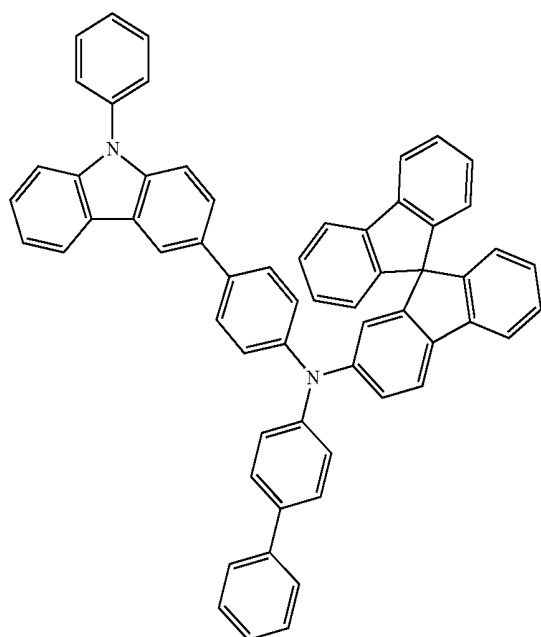


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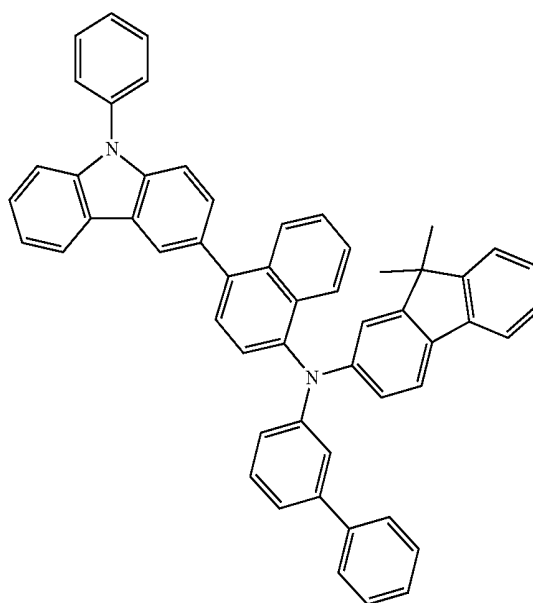
HT7



HT6

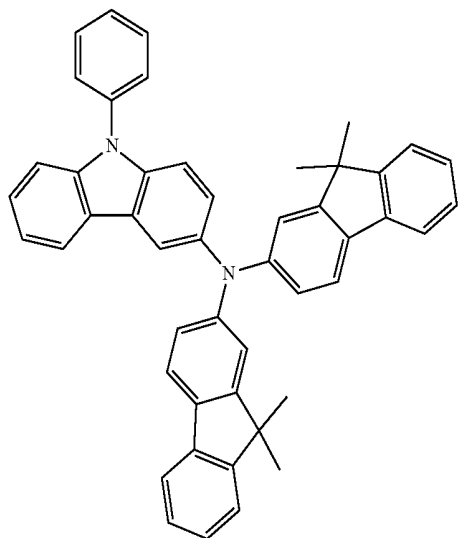


HT8



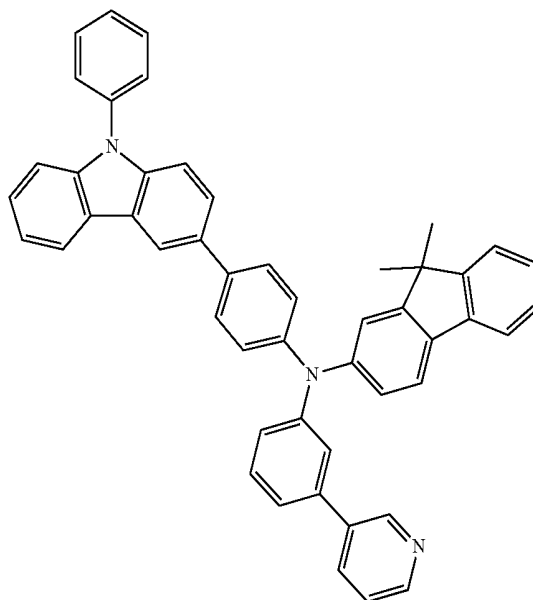
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HT9

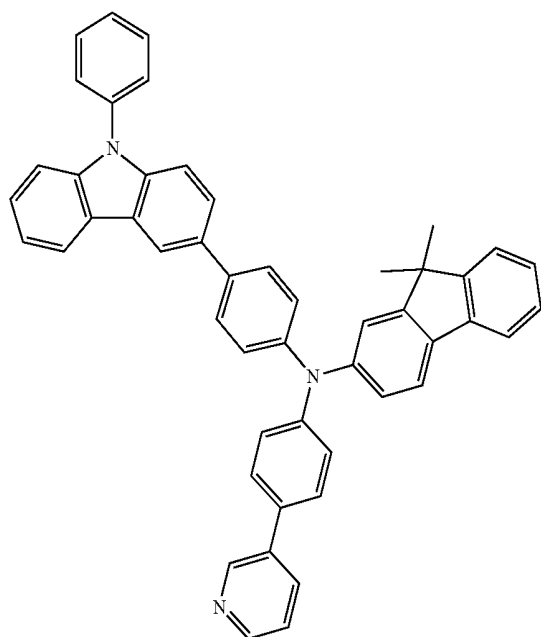


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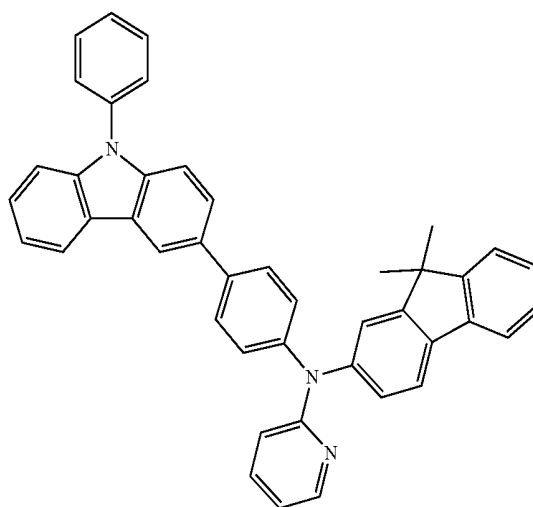
HT11



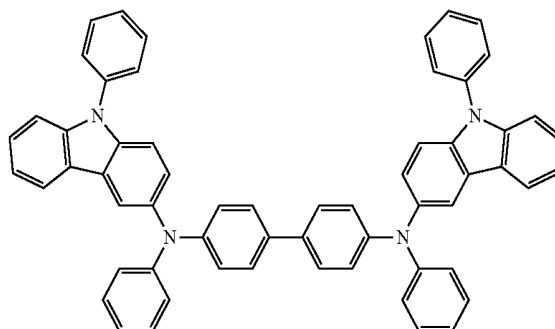
HT10



HT12

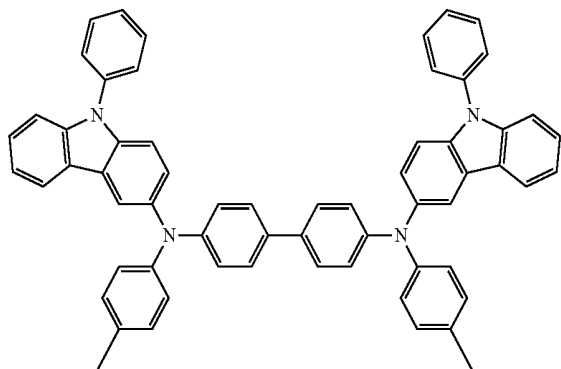


HT13

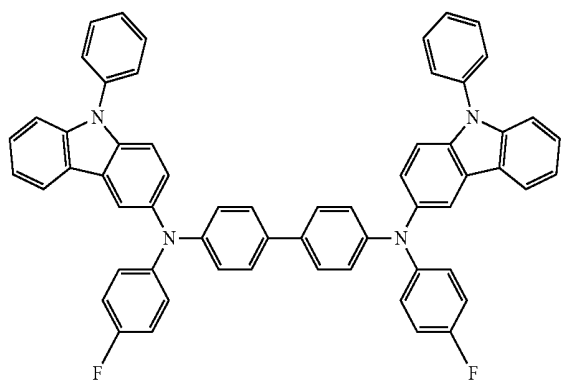


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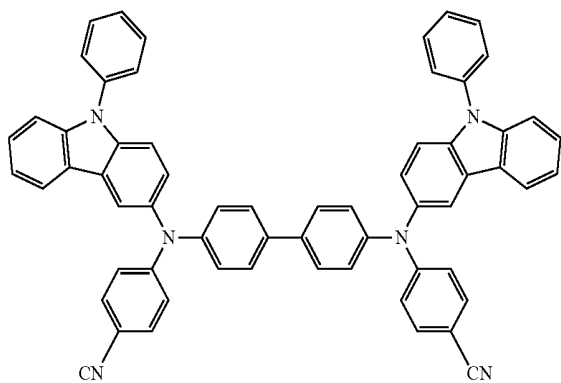
HT14



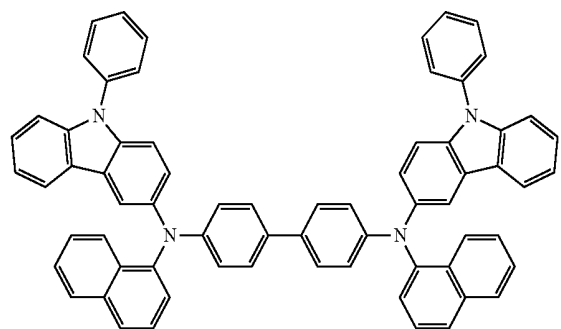
HT15



HT16

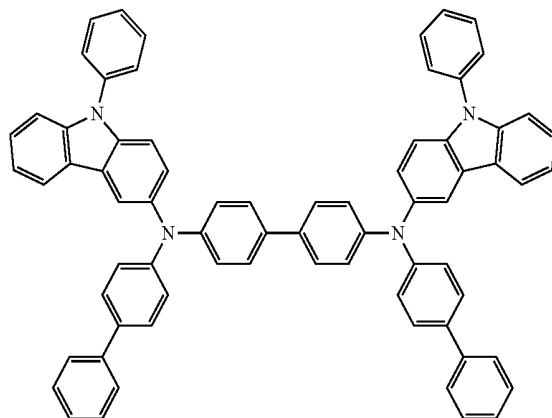


HT17

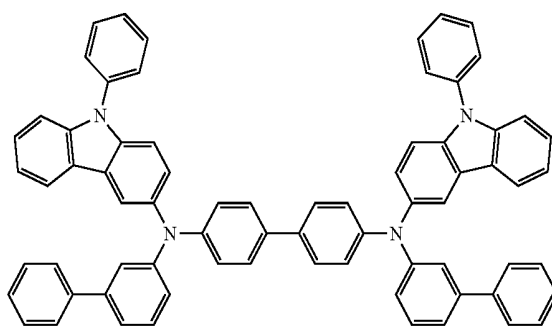


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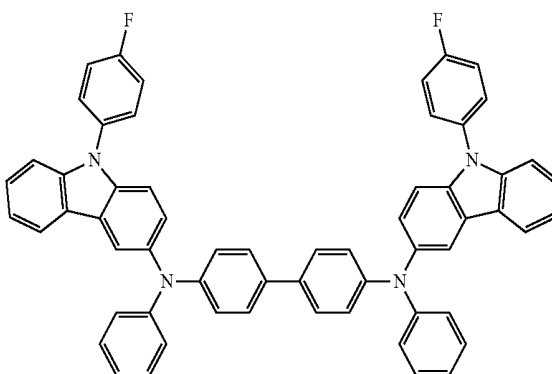
HT18



HT19

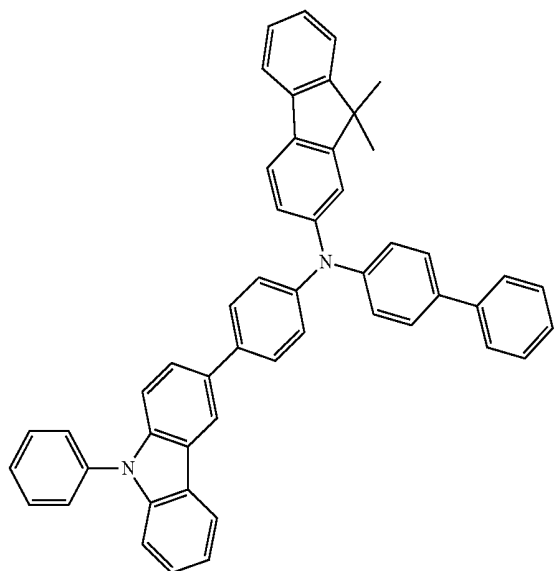


HT20



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HT21



[0207] The dibenzoborole-based compound may be homogeneously or non-homogeneously dispersed throughout the hole transport layer.

[0208] The amount of the dibenzoborole-based compound in the hole transport layer may be, based on about 100 parts by weight of the matrix material, about 0.5 part by weight to about 2 parts by weight, and in some embodiments, about 0.6 part by weight to about 1.2 parts by weight. When the amount of the dibenzoborole-based compound is within these ranges, the hole injection barrier may be low.

[0209] In some embodiments, the molar ratio of the dibenzoborole-based compound to the matrix material in the hole transport layer may be, for example, about 0.01 to about 0.05:about 1

$$\left(\text{e.g., } \frac{0.01-0.05}{1} \right).$$

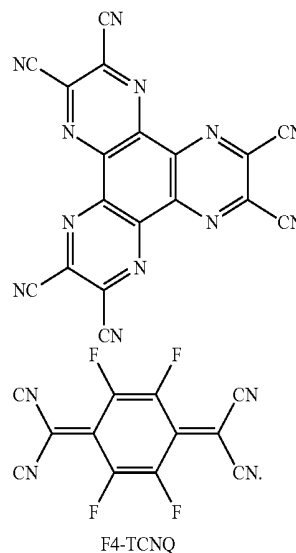
When the amount of the dibenzoborole-based compound is within these ranges, the hole injection barrier may be low.

[0210] The thickness of the hole transport region may be about 100 Å to about 10,000 Å, and in some embodiments, about 100 Å to about 1,000 Å. When the hole transport region includes a hole injection layer and a hole transport layer, the thickness of the hole injection layer may be about 100 Å to about 10,000 Å, and in some embodiments, about 100 Å to about 1,000 Å. The thickness of the hole transport layer may be about 50 Å to about 2,000 Å, and in some embodiments, about 100 Å to about 1,500 Å. When the thicknesses of the hole transport region, the hole injection layer, and the hole transport layer are within these ranges, excellent hole transport characteristics may be obtained without a substantial increase in driving voltage.

[0211] The hole transport region may include not only the dibenzoborole-based compound represented by Formula 1, but also quinone derivatives, such as tetracyanoquinodimethane (TCNQ) and/or 2,3,5,6-tetrafluoro-tetracyano-1,4-benzoquinodimethane (F4-TCNQ); metal oxides, such as

a tungsten oxide and/or a molybdenum oxide; and Compound HT-D1, but embodiments of the present disclosure are not limited thereto.

Compound HT-D1



[0212] The hole transport region may further include, in addition to the hole injection layer and the hole transport layer, at least one selected from a buffer layer and an electron blocking layer. Since the buffer layer may compensate for an optical resonance distance according to a wavelength of light emitted from the emission layer (e.g., be used to adjust the optical resonance distance to match the wavelength of light emitted from the emission layer), the light-emission efficiency of the resulting organic light-emitting device may be improved. Materials included in the hole transport region may be used as a material included in the buffer layer. In some embodiments, the electron blocking layer prevents or reduces injection of electrons from the electron transport region. The buffer layer and/or the electron blocking layer may include the dibenzoborole-based compound represented by Formula 1.

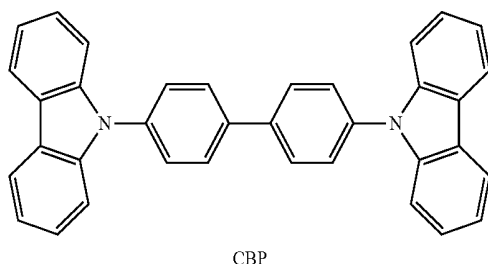
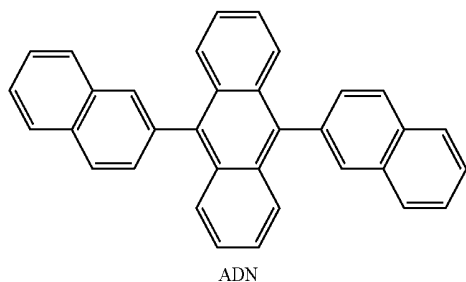
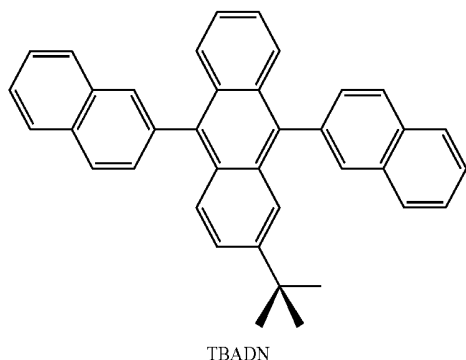
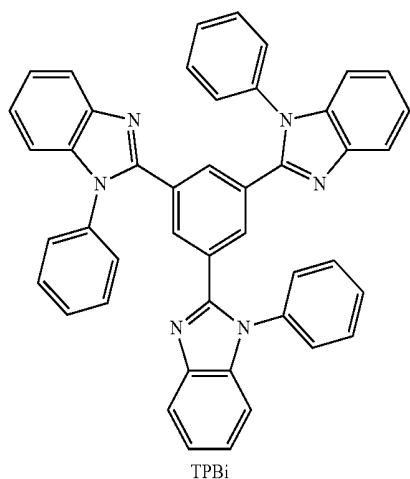
[0213] An emission layer may be formed on the first electrode 110 or on the hole transport region using one or more suitable methods, such as vacuum deposition, spin coating, casting, an LB method, ink-jet printing, laser printing, and/or LITI. When the emission layer is formed by vacuum deposition or spin coating, the deposition and coating conditions for the emission layer may be similar to the deposition and coating conditions for the hole injection layer.

[0214] 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, and/or a blue emission layer, according to a sub-pixel. In some embodiments, the emission layer may have a stacked structure of a red emission layer, a green emission layer, and a blue emission layer, and/or may include a red-light emission material, a green-light emission material, and a blue-light emission material, which are mixed with each other in a single layer to emit white light.

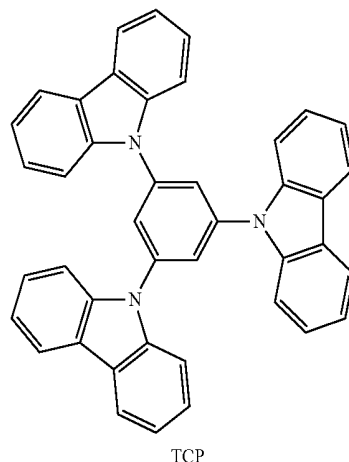
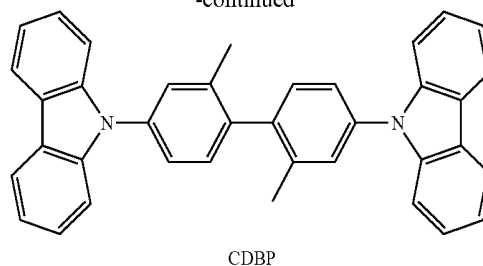
[0215] The emission layer may include the dibenzoborole-based compound represented by Formula 1.

[0216] The emission layer may include a host and a dopant.

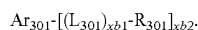
[0217] The host may include at least one selected from TPBi, TBADN, ADN (also known as "DNA"), CBP, CDBP, and TCP:



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[0218] In some embodiments, the host may further include a compound represented by Formula 301:



Formula 301

[0219] In Formula 301,

[0220] Ar_{301} may be selected from:

[0221] a naphthalene, a heptalene, a fluorene, a spirofluorene, a benzofluorene, a dibenzofluorene, a phenalene, a phenanthrene, an anthracene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a naphthacene, a picene, a perylene, a pentaphene, and an indenoanthracene; and

[0222] a naphthalene, a heptalene, a fluorene, a spirofluorene, a benzofluorene, a dibenzofluorene, a phenalene, a phenanthrene, an anthracene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a naphthacene, a picene, a perylene, a pentaphene, and an indenoanthracene, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60} alkynyl group, a C_1 - C_{60} alkoxy group, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, a terphenyl group, and —Si(Q_{301})(Q_{302})(Q_{303}), wherein Q_{301} to Q_{303} may each independently be selected from hydrogen, a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_6 - C_{60} aryl group, and a C_1 - C_{60} heteroaryl group,

[0223] L_{301} may be the same as defined herein in connection with L_1 ;

[0224] R_{301} may be selected from:

[0225] a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group;

[0226] a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzo-fluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

[0227] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzo-fluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazole group, and a triazinyl group; and

[0228] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzo-fluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzo-fluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group,

[0229] $xb1$ may be selected from 0, 1, 2, and 3, and

[0230] $xb2$ may be selected from 1, 2, 3, and 4.

[0231] In some embodiments, in Formula 301, L_{301} may be selected from:

[0232] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-fluorenylene group, a benzo-fluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, and a chrysenylene group; and

[0233] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-fluorenylene group, a benzo-fluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, and a chrysenylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a

carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzo-fluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, and a chrysenyl group,

[0234] R_{301} may be selected from:

[0235] a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group;

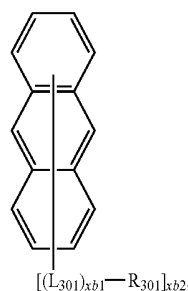
[0236] a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzo-fluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, and a chrysenyl group;

[0237] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzo-fluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, and a chrysenyl group; and

[0238] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzo-fluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, and a chrysenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzo-fluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, and a chrysenyl group, but embodiments of the present disclosure are not limited thereto.

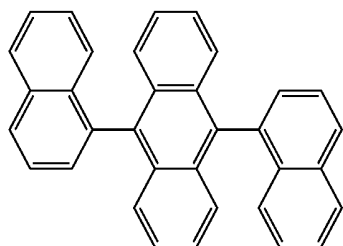
[0239] In some embodiments, the host may include a compound represented by Formula 301A:

Formula 301A

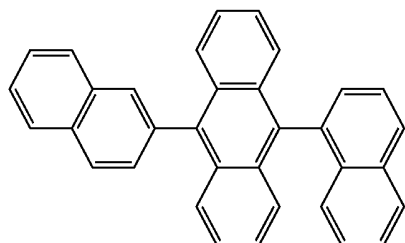


[0240] The descriptions for Formula 301A (e.g., for the substituents and subscripts in Formula 301A) may be the same as described earlier herein.

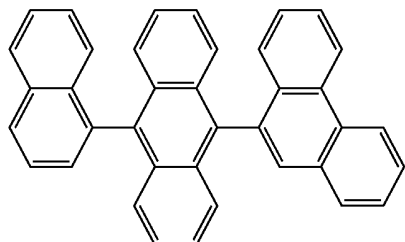
[0241] The compound represented by Formula 301 may include at least one compound selected from Compounds H1 to H42, but embodiments of the present disclosure are not limited thereto:



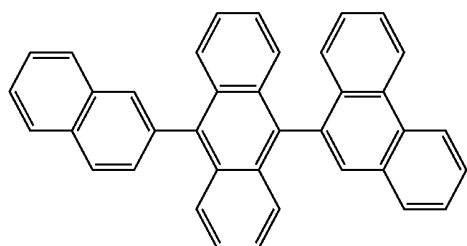
H1



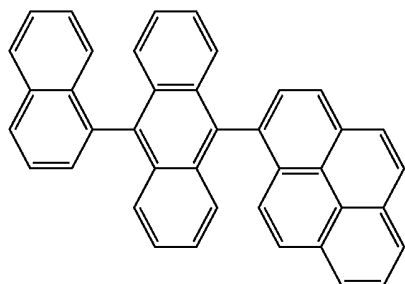
H2



H3

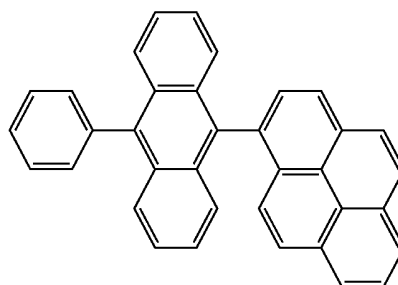


H4

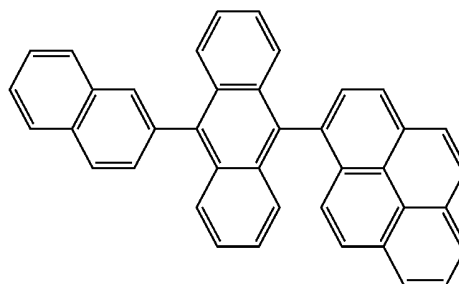


H5

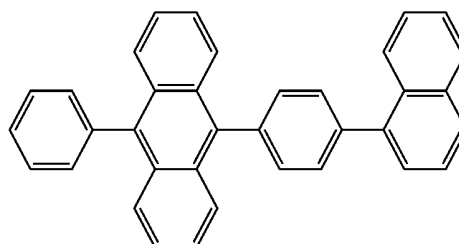
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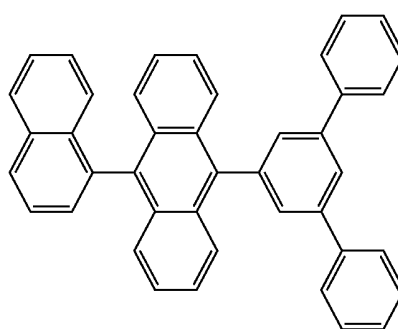
H6



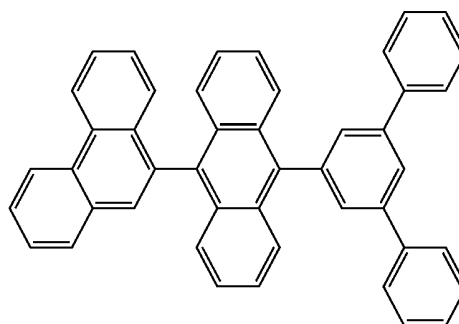
H7



H8



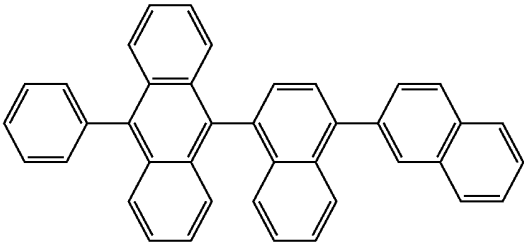
H9



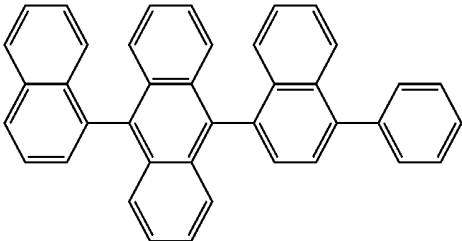
H10

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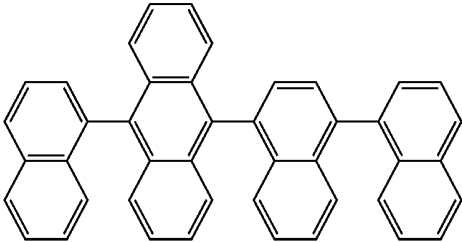
H11



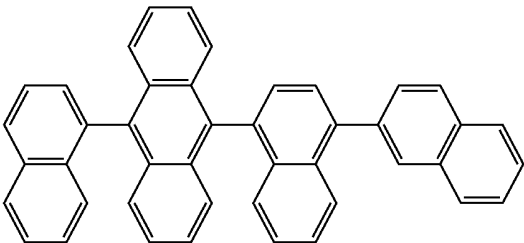
H12



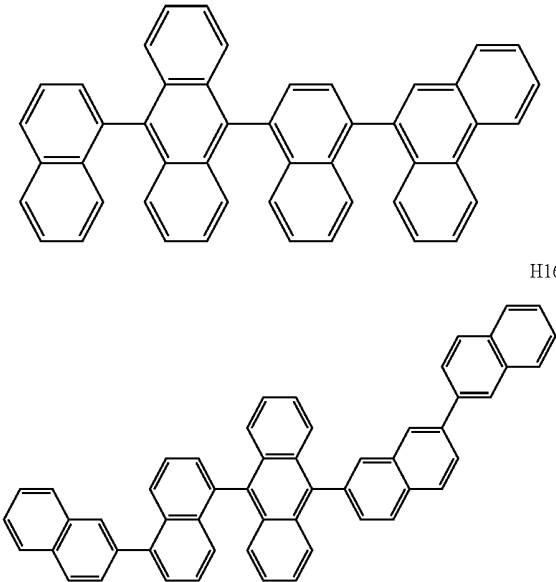
H14



H15

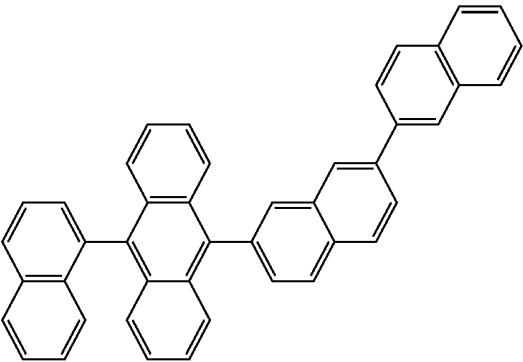


H16

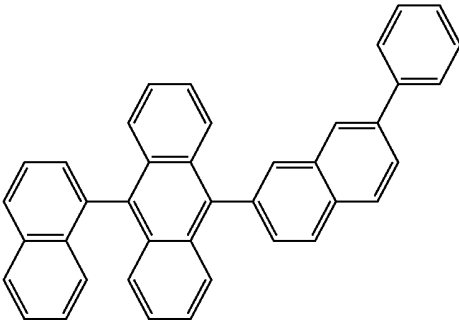


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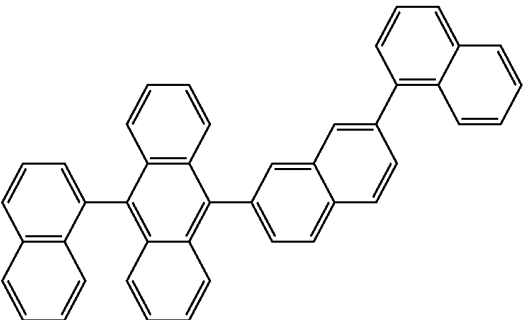
H17



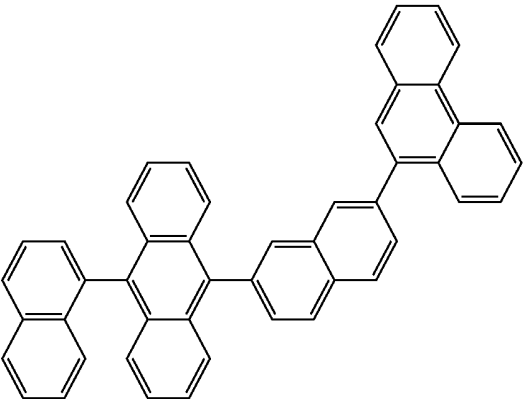
H18



H19

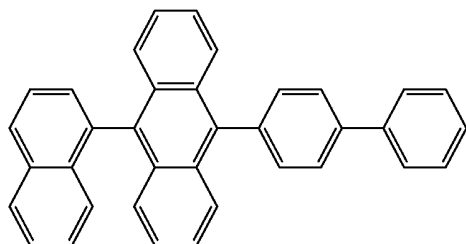


H20



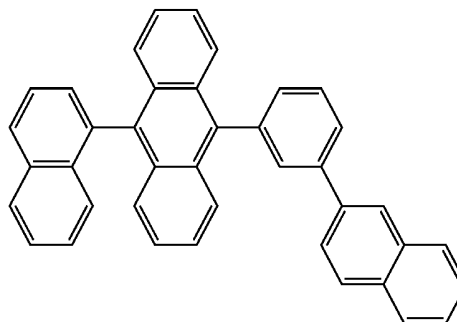
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H21

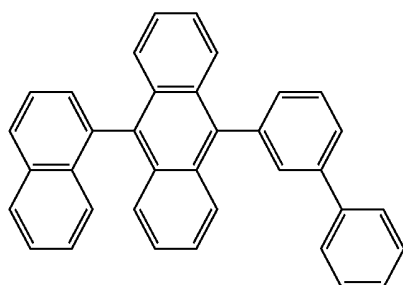


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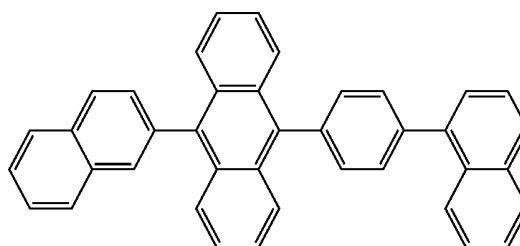
H26



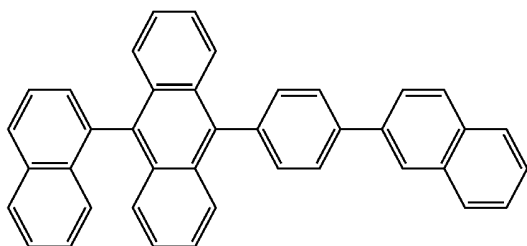
H22



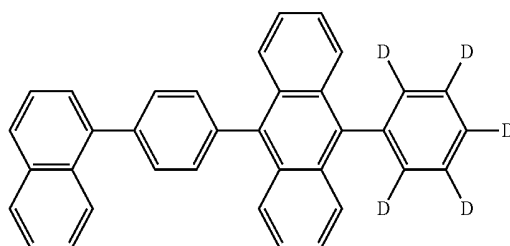
H27



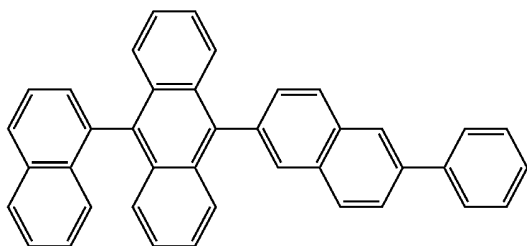
H23



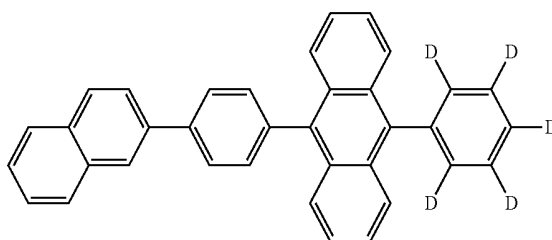
H28



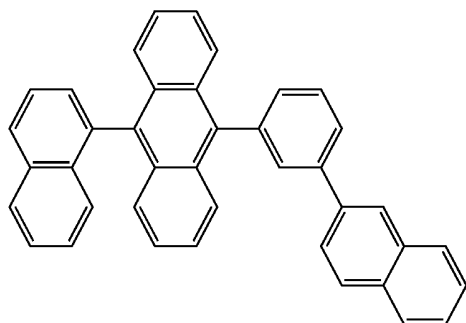
H24



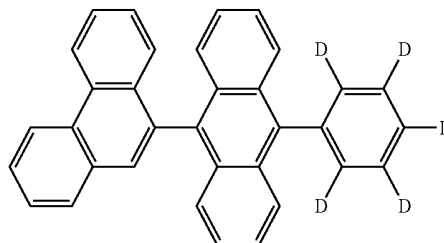
H29



H25

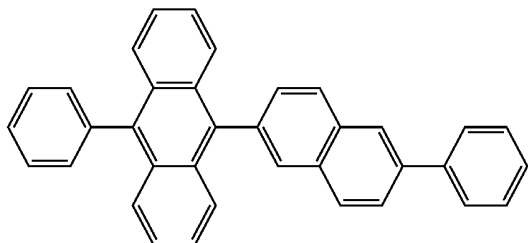


H30

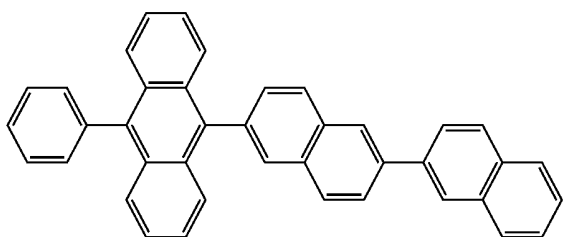


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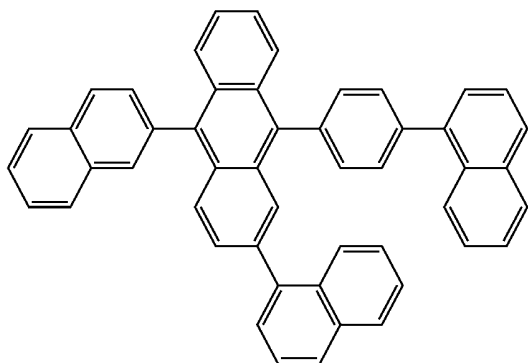
H31



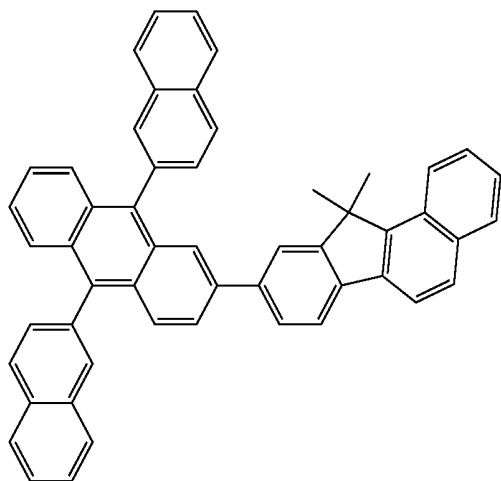
H32



H33

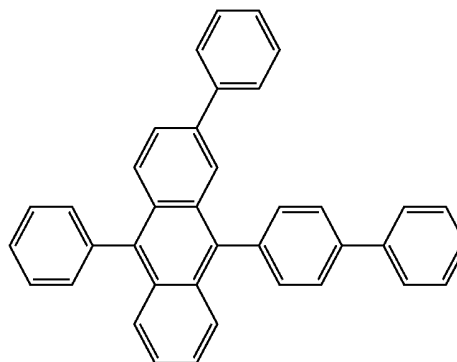


H34

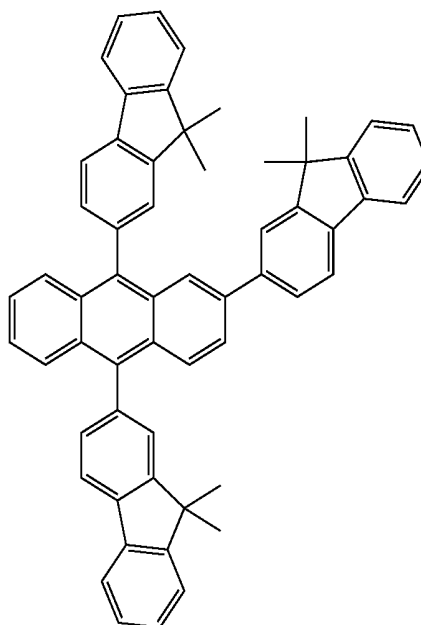


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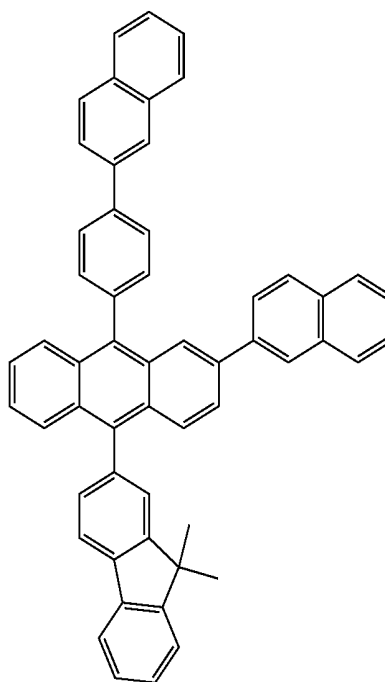
H35



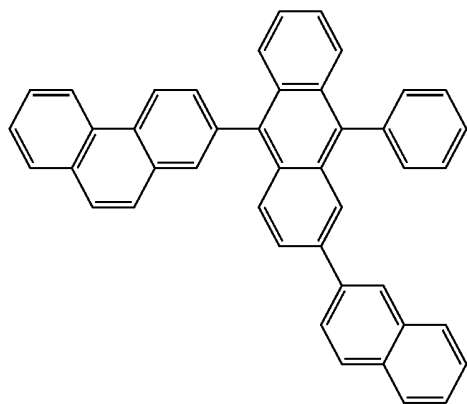
H36



H37

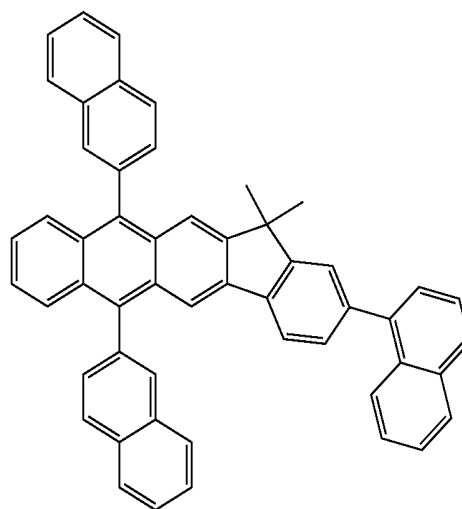


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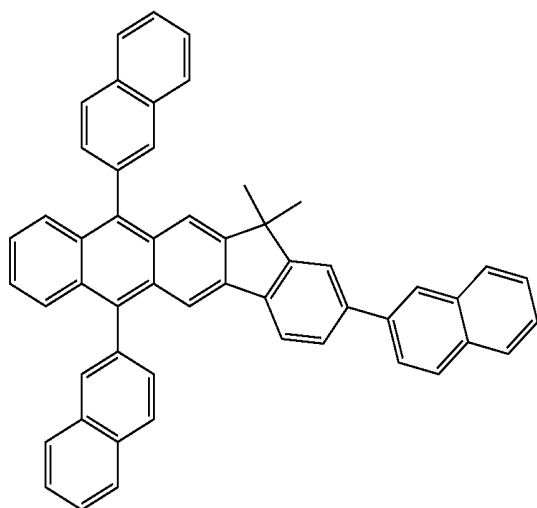
H38

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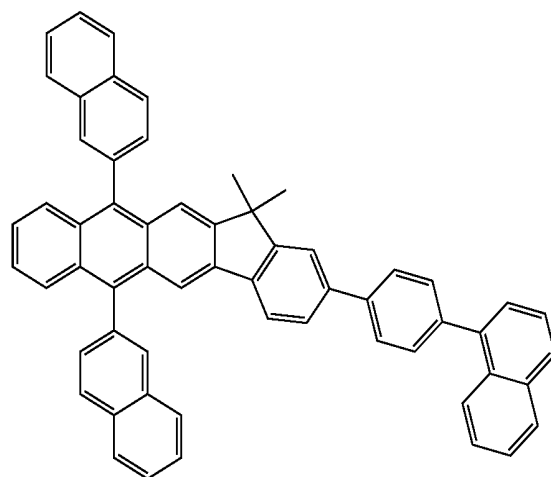


H41

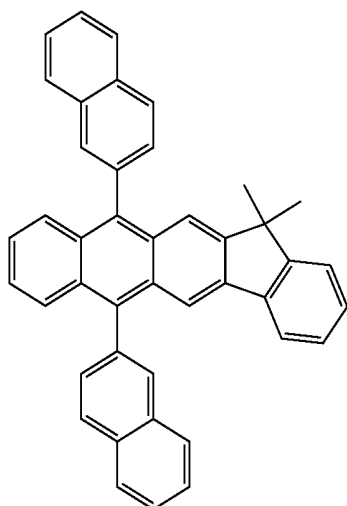
H39



H42

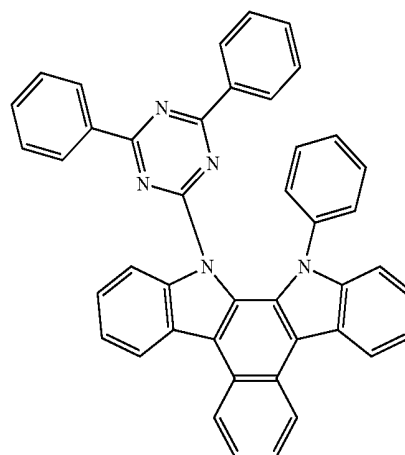


H40

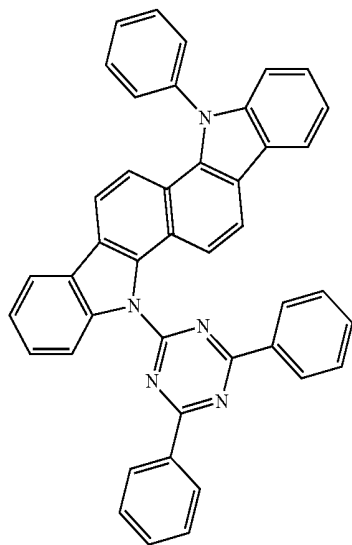


[0242] In some embodiments, the host may include at least one selected from Compounds H43 to H49, but embodiments of the present disclosure are not limited thereto:

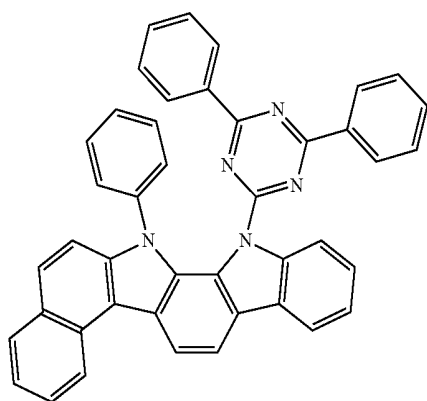
H43



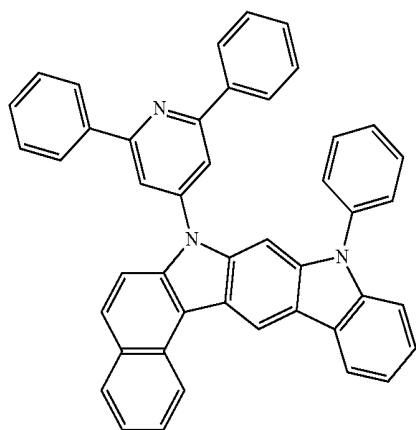
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H44

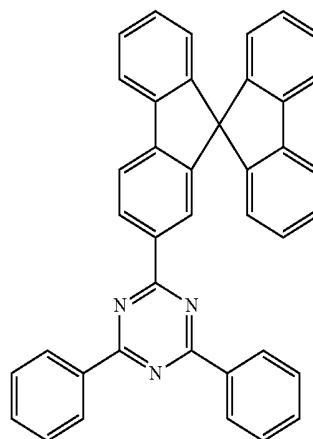


H45

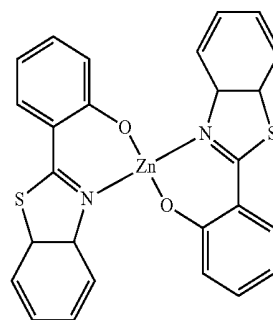


H46

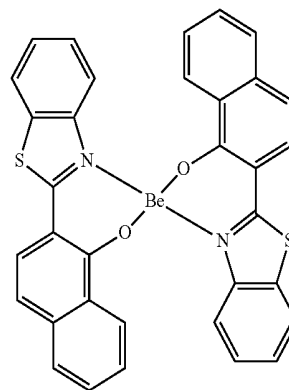
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H47



H48

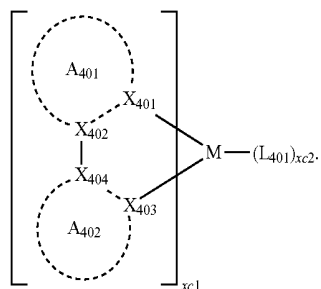


H49

[0243] The dopant may include at least one selected from a fluorescent dopant and a phosphorescent dopant.

[0244] The phosphorescent dopant may include an organometallic complex represented by Formula 401:

Formula 401



[0245] In Formula 401,

[0246] M may be selected from iridium (Ir), platinum (Pt), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), and thulium (Tm);

[0247] X_{401} to X_{404} may each independently be selected from nitrogen and carbon;

[0248] the A_{401} and A_{402} rings may each independently be selected from a substituted or unsubstituted benzene, a substituted or unsubstituted naphthalene, a substituted or unsubstituted fluorene, a substituted or unsubstituted spiro-fluorene, a substituted or unsubstituted indene, a substituted or unsubstituted pyrrole, a substituted or unsubstituted thiophene, a substituted or unsubstituted furan, a substituted or unsubstituted imidazole, a substituted or unsubstituted pyrazole, a substituted or unsubstituted thiazole, a substituted or unsubstituted isothiazole, a substituted or unsubstituted oxazole, a substituted or unsubstituted isoxazole, a substituted or unsubstituted pyridine, a substituted or unsubstituted pyrazine, a substituted or unsubstituted pyrimidine, a substituted or unsubstituted pyridazine, a substituted or unsubstituted quinoline, a substituted or unsubstituted isoquinoline, a substituted or unsubstituted benzoquinoline, a substituted or unsubstituted quinoxaline, a substituted or unsubstituted quinazoline, a substituted or unsubstituted carbazole, a substituted or unsubstituted benzimidazole, a substituted or unsubstituted benzofuran, a substituted or unsubstituted benzothiophene, a substituted or unsubstituted isobenzothiophene, a substituted or unsubstituted benzoxazole, a substituted or unsubstituted isobenzoxazole, a substituted or unsubstituted triazole, a substituted or unsubstituted oxadiazole, a substituted or unsubstituted triazine, a substituted or unsubstituted dibenzofuran, and a substituted or unsubstituted dibenzothiophene;

[0249] at least one substituent of the substituted benzene, substituted naphthalene, substituted fluorene, substituted spiro-fluorene, substituted indene, substituted pyrrole, substituted thiophene, substituted furan, substituted imidazole, substituted pyrazole, substituted thiazole, substituted isothiazole, substituted oxazole, substituted isoxazole, substituted pyridine, substituted pyrazine, substituted pyrimidine, substituted pyridazine, substituted quinoline, substituted isoquinoline, substituted benzoquinoline, substituted quinoxaline, substituted quinazoline, substituted carbazole, substituted benzimidazole, substituted benzofuran, substituted benzothiophene, substituted isobenzothiophene, substituted benzoxazole, substituted isobenzoxazole, substituted triazole, substituted oxadiazole, substituted triazine, substituted dibenzofuran, and substituted dibenzothiophene may be selected from:

[0250] deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60} alkynyl group, and a C_1 - C_{60} alkoxy group;

[0251] a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60} alkynyl group, and a C_1 - C_{60} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_3 - C_{10} cycloalkyl group, a

C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, a terphenyl group, —N(Q_{401})(Q_{402}), —Si(Q_{403})(Q_{404})(Q_{405}), and —B(Q_{406})(Q_{407});

[0252] a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group;

[0253] a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60} alkynyl group, a C_1 - C_{60} alkoxy group, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, a terphenyl group, —N(Q_{411})(Q_{412}), —Si(Q_{413})(Q_{414})(Q_{415}) and —B(Q_{416})(Q_{417}), and

[0254] —N(Q_{421})(Q_{422}), —Si(Q_{423})(Q_{424})(Q_{425}), and —B(Q_{426})(Q_{427}).

[0255] L_{401} may be an organic ligand,

[0256] xc1 may be selected from 1, 2, and 3; and

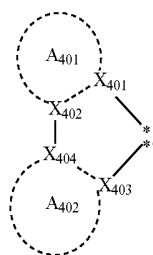
[0257] xc2 may be selected from 0, 1, 2, and 3.

[0258] L_{401} may be any suitable monovalent, divalent, or trivalent organic ligand. For example, L_{401} may be selected from a halogen ligand (e.g., Cl and/or F), a diketone ligand (e.g., acetylacetonate, 1,3-diphenyl-1,3-propanedionate, 2,2,6,6-tetramethyl-3,5-heptanedionate, and/or hexafluoroacetonate), a carboxylic acid ligand (e.g., picolinate, dimethyl-3-pyrazolecarboxylate, and/or benzoate), a carbon monoxide ligand, an isonitrile ligand, a cyano ligand, and a phosphorous ligand (e.g., phosphine and/or phosphite), but embodiments of the present disclosure are not limited thereto.

[0259] When A_{401} in Formula 401 includes a plurality of substituents, the plurality of substituents of A_{401} may bind (e.g., couple) to each other to form a saturated or unsaturated ring.

[0260] When A_{402} in Formula 401 includes a plurality of substituents, the plurality of substituents of A_{402} may bind (e.g., couple) to each other to form a saturated or unsaturated ring.

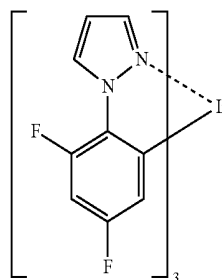
[0261] When xc1 in Formula 401 is 2 or greater, a plurality of ligands



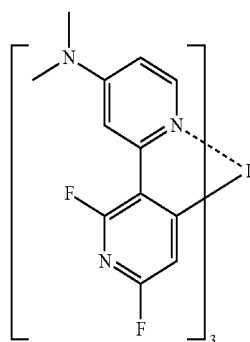
in Formula 401 may be identical to or different from each other. In Formula 401, when xc1 is 2 or greater, A₄₀₁ and A₄₀₂ may be directly connected or connected via a linking group (for example, a C₁-C₅ alkylene group, —N(R')— (where R' is a C₁-C₁₀ alkyl group or a C₆-C₂₀ aryl group), or —C(=O)—) to another adjacent ligand of A₄₀₁ and A₄₀₂, respectively.

[0262] The phosphorescent dopant may include at least one selected from Compounds PD1 to PD74, but embodiments of the present disclosure are not limited thereto.

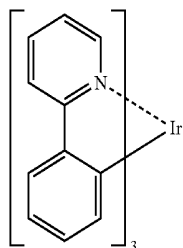
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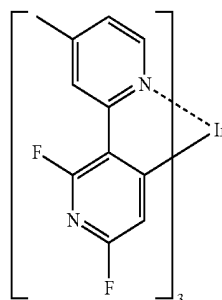
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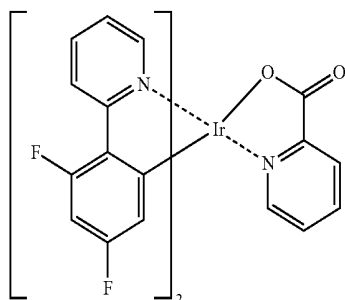
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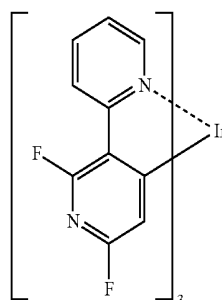
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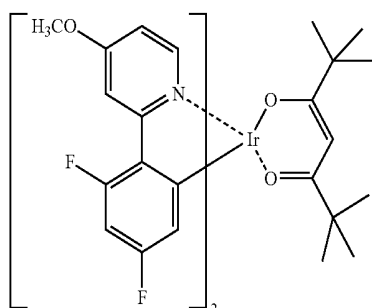
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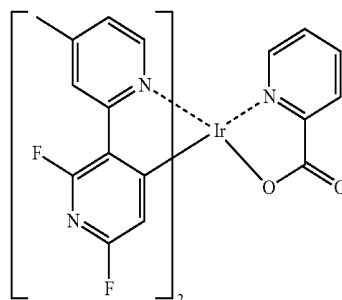
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PD7

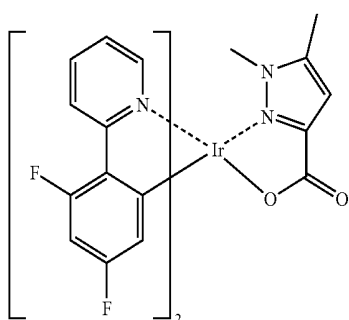
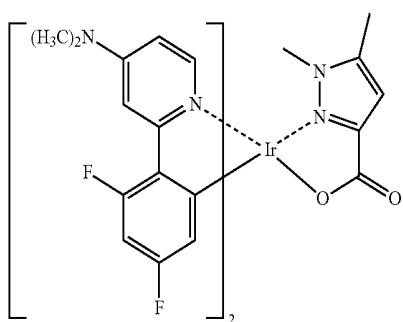
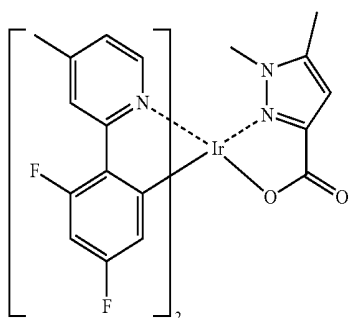
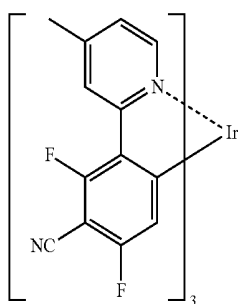
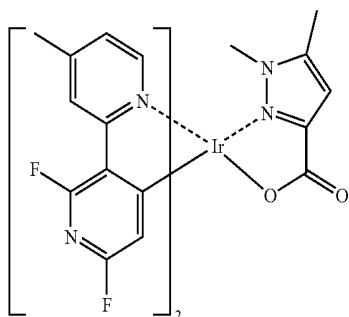


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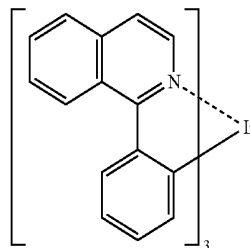
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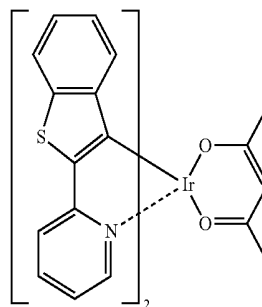
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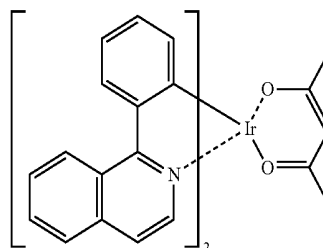
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PD10



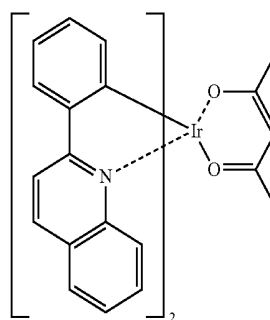
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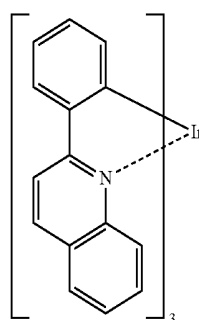
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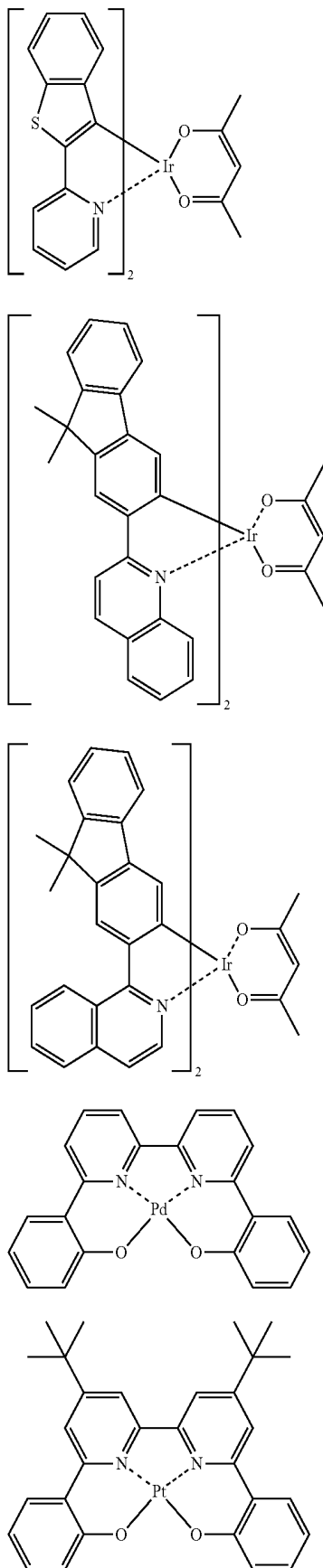
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PD13



PD18

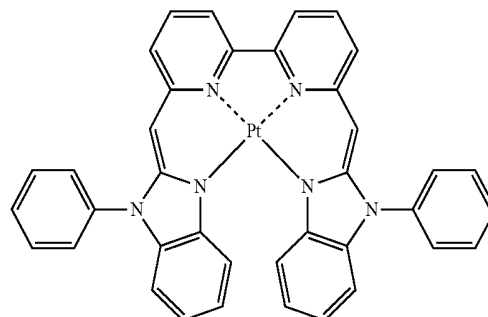
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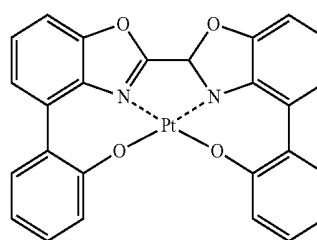
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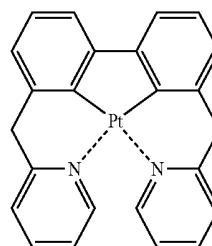
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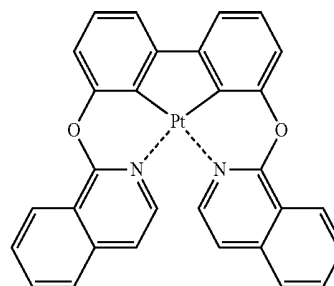
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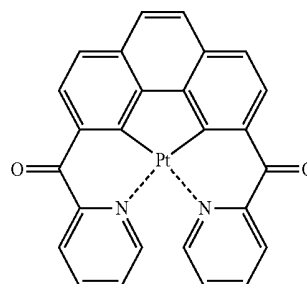
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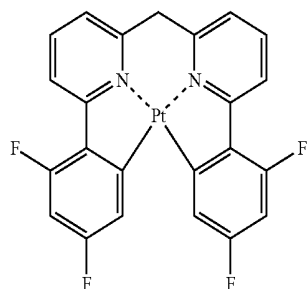
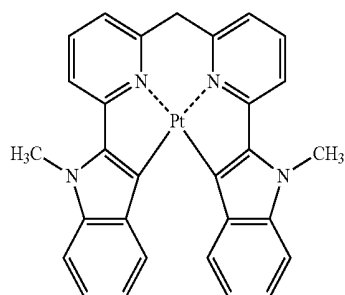
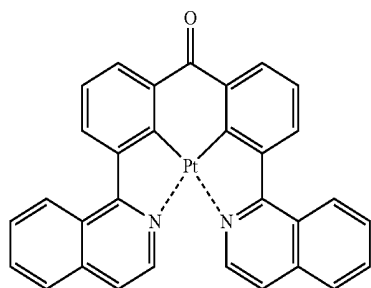
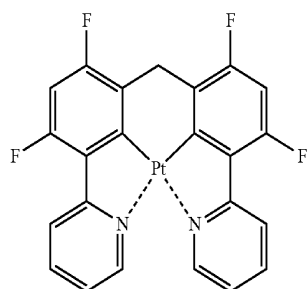
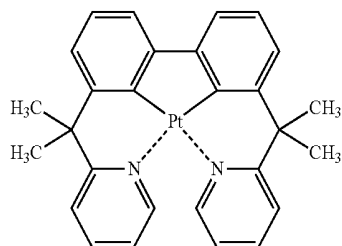


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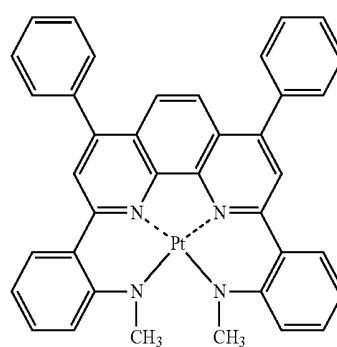
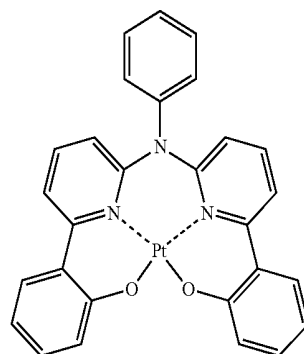
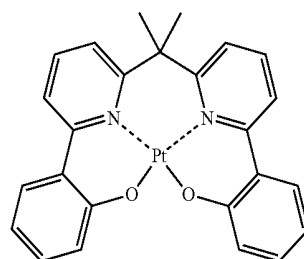
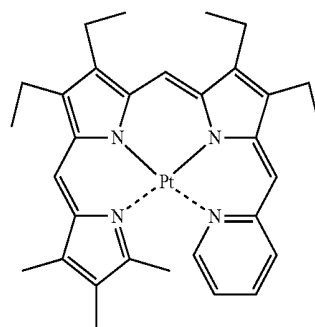
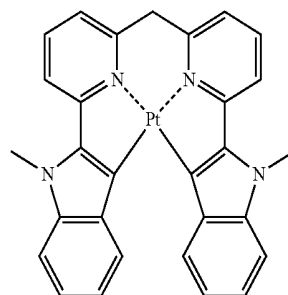
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PD29

PD34

PD30

PD35

PD31

PD36

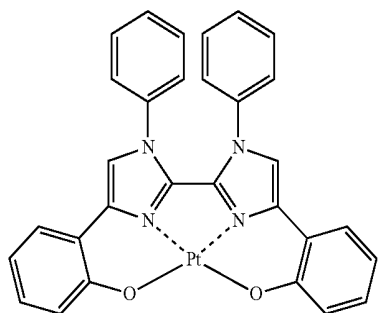
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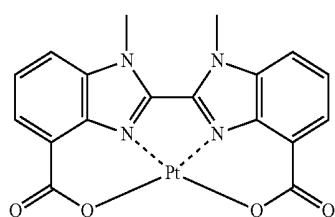
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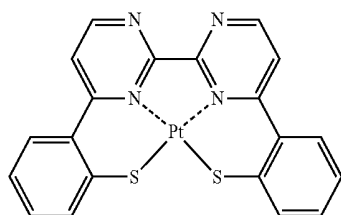
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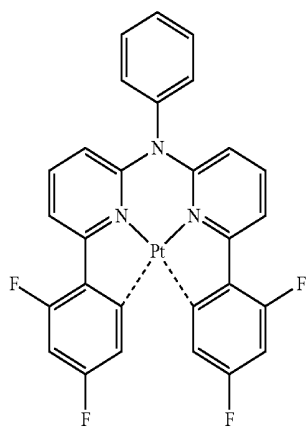
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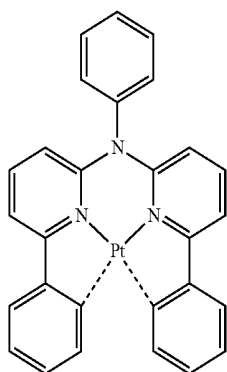
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PD41

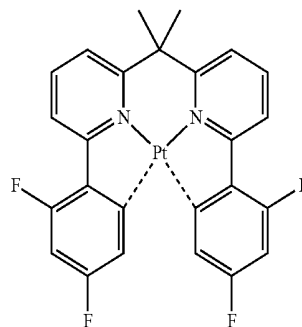


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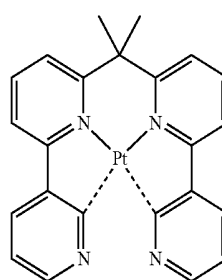


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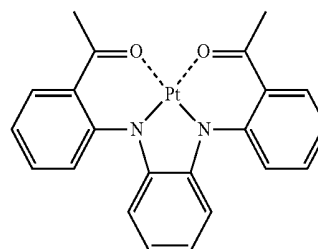
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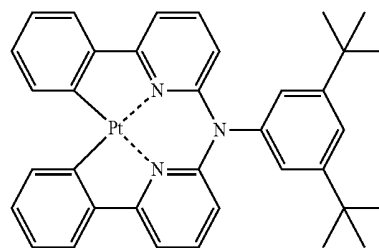
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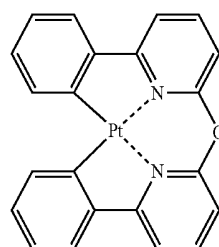
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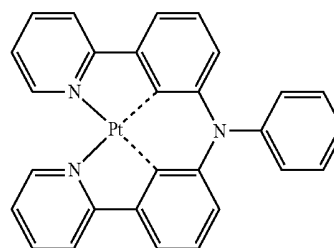
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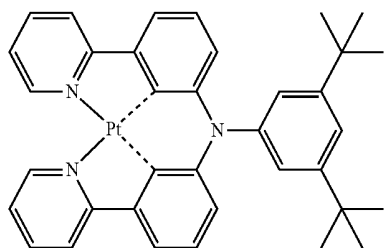


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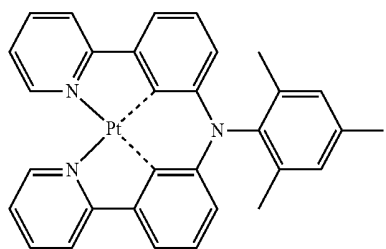


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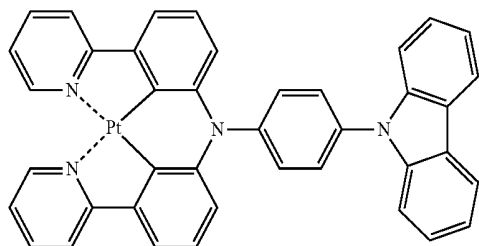
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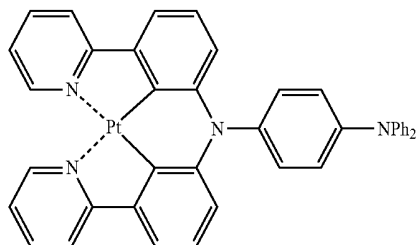
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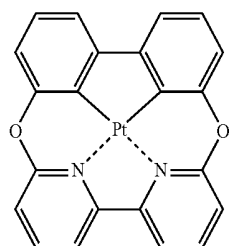
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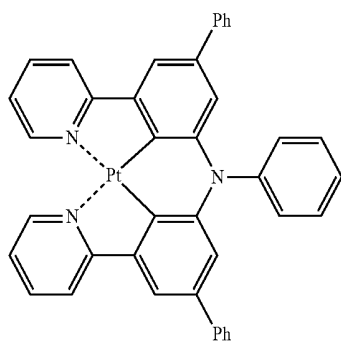
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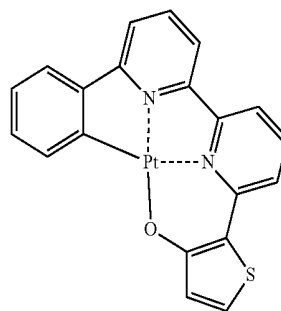


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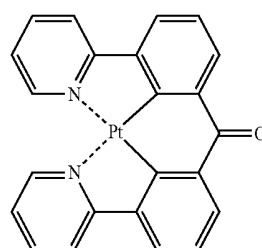


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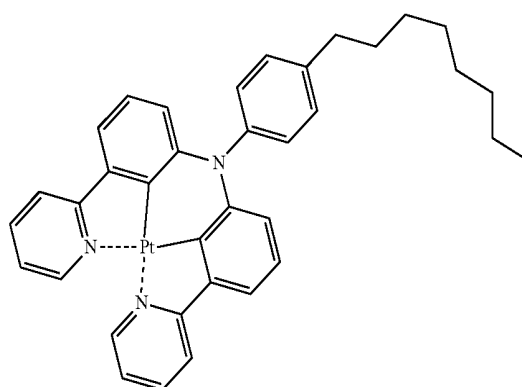
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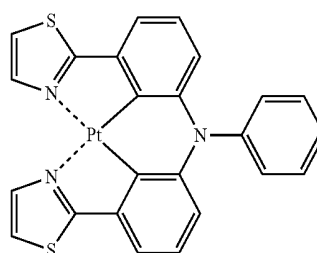
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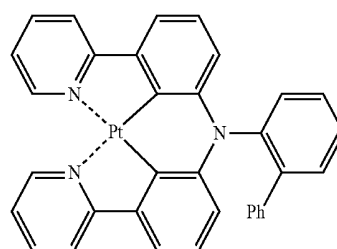
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PD58

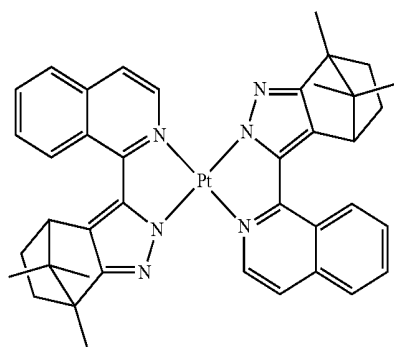


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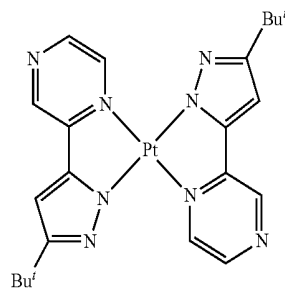
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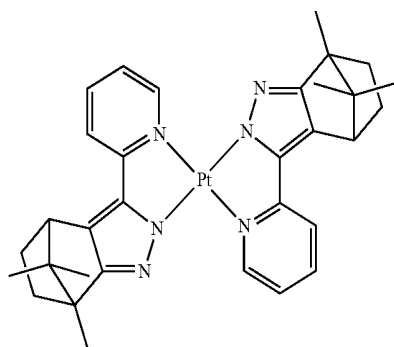


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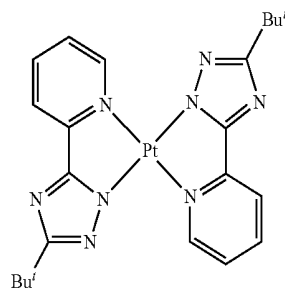
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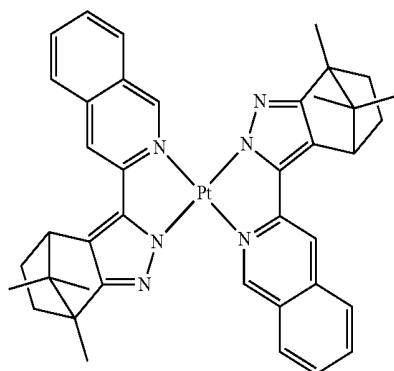
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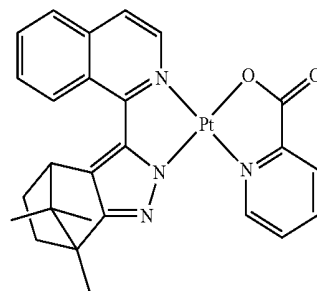
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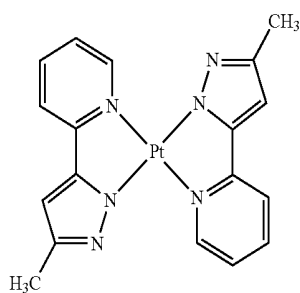
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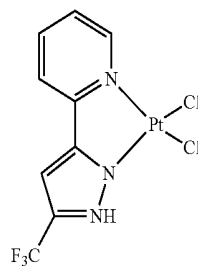
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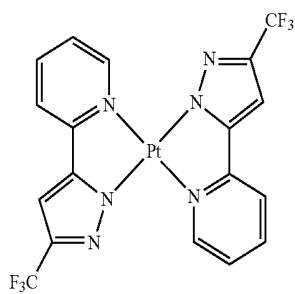
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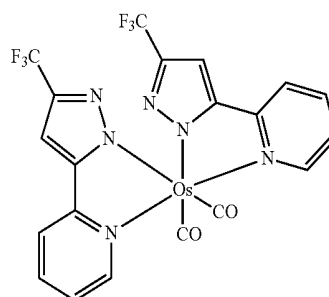
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PD69

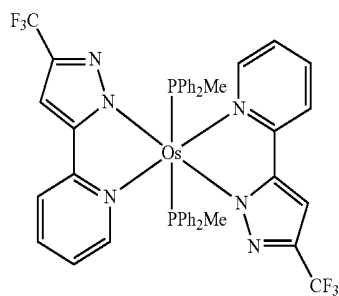


PD65



PD70

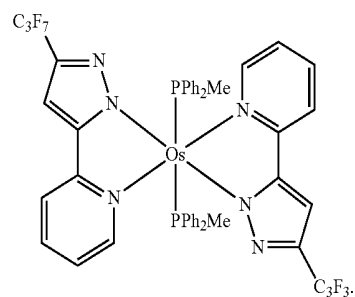
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PD71

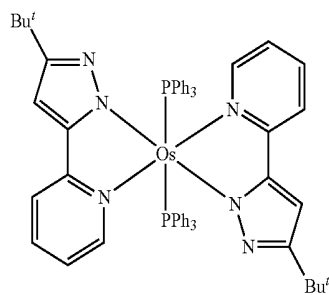
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PD74

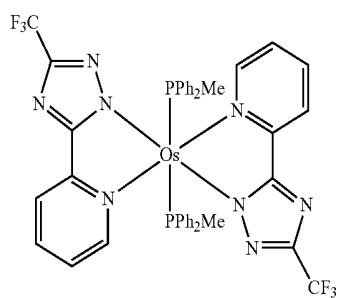
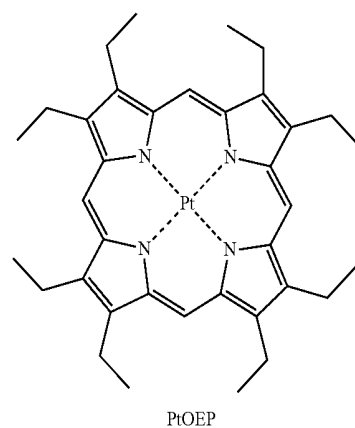


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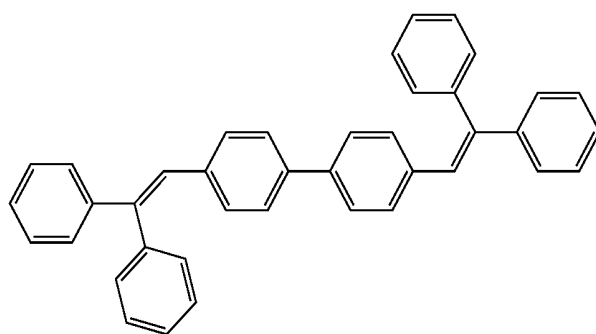
[0263] In some embodiments, the phosphorescent dopant may include PtOEP:



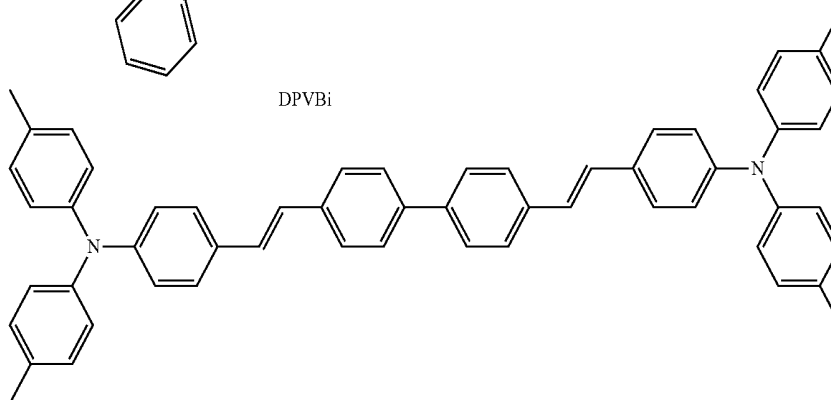
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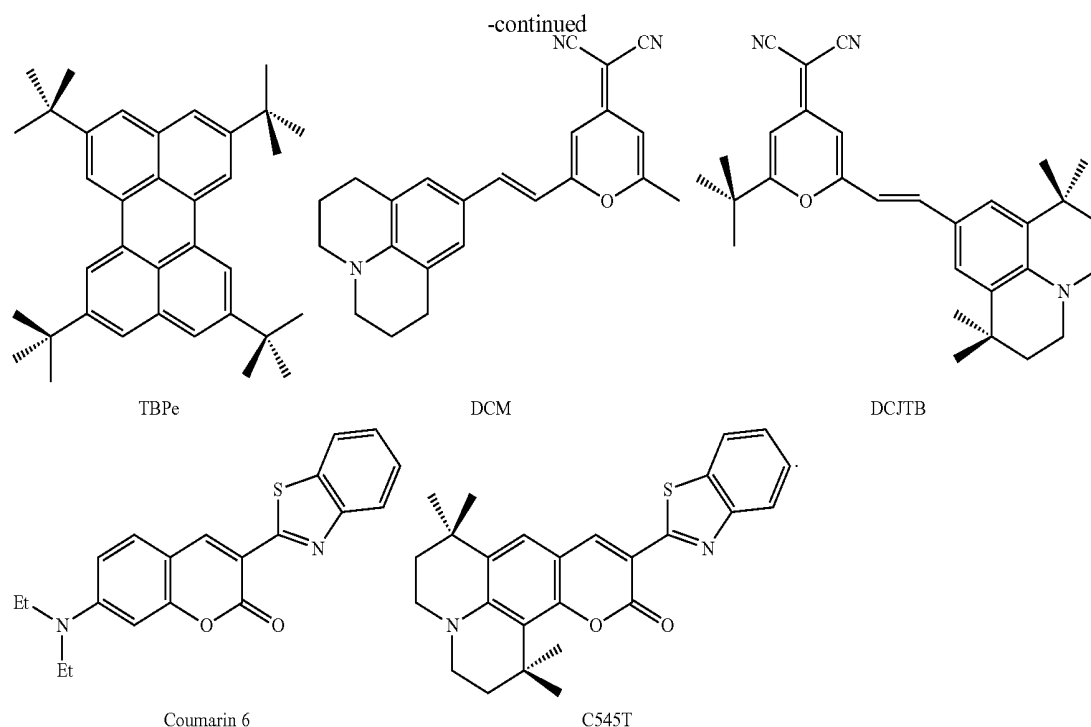
[0264] The fluorescent dopant may include at least one selected from DPVBi, DPAVBi, TBPe, DCM, DCJTb, Coumarin 6, and C545T.



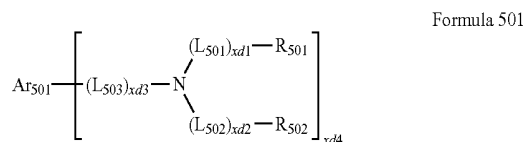
DPVBi



DPAVBi



[0265] In some embodiments, the fluorescent dopant may include a compound represented by Formula 501:



[0266] In Formula 501,

[0267] Ar_{501} may be selected from a naphthalene, a heptalene, a fluorene, a spiro-fluorene, a benzofluorene, a dibenzofluorene, a phenalene, a phenanthrene, an anthracene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a naphthacene, a picene, a perylene, a pentaphene, and an indenoanthracene; and

[0268] a naphthalene, a heptalene, a fluorene, a spiro-fluorene, a benzofluorene, a dibenzofluorene, a phenalene, a phenanthrene, an anthracene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a naphthacene, a picene, a perylene, a pentaphene, and an indenoanthracene, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a $\text{C}_1\text{-C}_{60}$ alkyl group, a $\text{C}_2\text{-C}_{60}$ alkenyl group, a $\text{C}_2\text{-C}_{60}$ alkynyl group, a $\text{C}_1\text{-C}_{60}$ alkoxy group, a $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, a $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_6\text{-C}_{60}$ aryloxy group, a $\text{C}_6\text{-C}_{60}$ arylthio group, a $\text{C}_1\text{-C}_{60}$ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group,

a terphenyl group, and $-\text{Si}(\text{Q}_{501})(\text{Q}_{502})(\text{Q}_{503})$, wherein Q_{501} to Q_{503} may be each independently selected from hydrogen, a $\text{C}_1\text{-C}_{60}$ alkyl group, a $\text{C}_2\text{-C}_{60}$ alkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, and a $\text{C}_1\text{-C}_{60}$ heteroaryl group,

[0269] L_{501} to L_{503} may be the same as described herein in connection with L_{201} ;

[0270] R_{501} and R_{502} may each independently be selected from:

[0271] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazole group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

[0272] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, 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 amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a $\text{C}_1\text{-C}_{20}$ alkyl group, a $\text{C}_1\text{-C}_{20}$ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a

pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group.

[0273] xd1 to xd3 may each independently be an integer selected from 0, 1, 2, and 3, and

[0274] xb4 may be selected from 1, 2, 3, and 4.

[0275] The amount of the dopant in the emission layer may be, in general, about 0.01 to about 15 parts by weight based on 100 parts by weight of the host, but embodiments of the present disclosure are not limited thereto.

[0276] The thickness of the emission layer may be about 100 Å to about 1000 Å, and in some embodiments, about 200 Å to about 600 Å. When the thickness of the emission layer is within this range, excellent light-emission characteristics may be achieved without a substantial increase in driving voltage.

[0277] An electron transport region may be on the emission layer.

[0278] The electron transport region may include at least one selected from a hole blocking layer, an electron transport layer, and an electron injection layer, but embodiments of the present disclosure are not limited thereto.

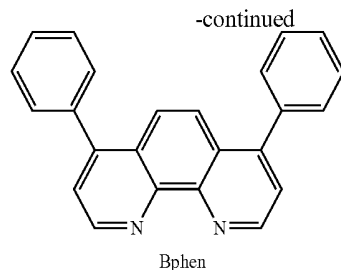
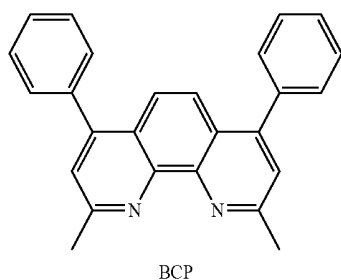
[0279] In some embodiments, the electron transport region may have a structure of electron transport layer/electron injection layer and/or a structure of hole blocking layer/electron transport layer/electron injection layer, wherein layers of each structure are sequentially stacked from the emission layer in the stated order, but embodiments of the present disclosure are not limited thereto.

[0280] In some embodiments, the organic layer 150 of the organic light-emitting device includes an electron transport region between the emission layer and the second electrode 190.

[0281] The electron transport region may include a hole blocking layer. The hole blocking layer may be formed, when the emission layer includes a phosphorescent dopant, to prevent or reduce diffusion of excitons and/or holes into an electron transport layer.

[0282] When the electron transport region includes a hole blocking layer, the hole blocking layer may be formed on the emission layer using one or more suitable methods, such as vacuum deposition, spin coating, casting, an LB method, ink-jet printing, laser printing, and/or LITI. When the hole blocking layer is formed by vacuum deposition and/or spin coating, the deposition and coating conditions for the hole blocking layer may be similar to the deposition and coating conditions used for the hole injection layer.

[0283] The hole blocking layer may include, for example, at least one selected from BCP and Bphen, but embodiments of the present disclosure are not limited thereto:

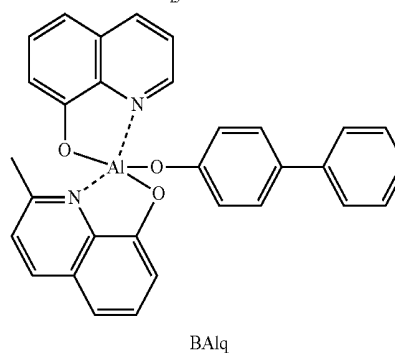
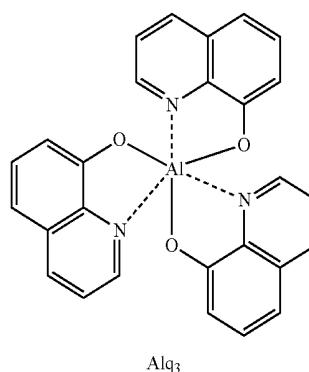


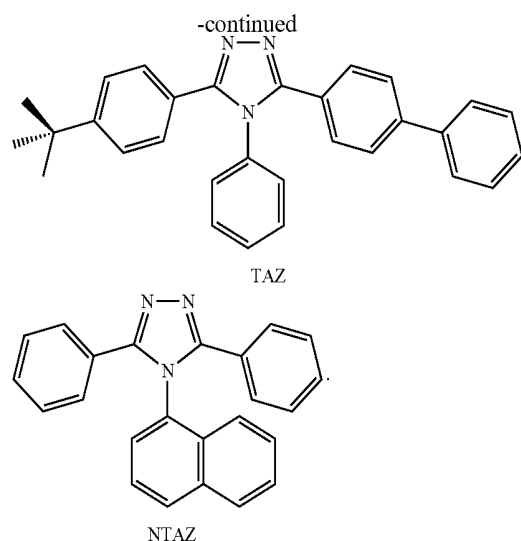
[0284] The thickness of the hole blocking layer may be about 20 Å to about 1000 Å, and in some embodiments, about 30 Å to about 300 Å. When the thickness of the hole blocking layer is within this range, excellent hole blocking characteristics may be achieved without a substantial increase in driving voltage.

[0285] The electron transport region may include an electron transport layer. The electron transport layer may be formed on the emission layer and/or on the hole blocking layer using one or more suitable methods, such as vacuum deposition, spin coating, casting, an LB method, ink-jet printing, laser printing, and/or LITI. When the electron transport layer is formed using vacuum deposition and/or spin coating, the vacuum deposition and coating conditions for the electron transport layer may be similar to the vacuum deposition and coating conditions used for the hole injection layer.

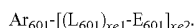
[0286] In some embodiments, the organic layer 150 of the organic light-emitting device includes an electron transport region positioned between the emission layer and the second electrode 190. The electron transport region may include at least one selected from an electron transport layer and an electron injection layer, but is not limited thereto.

[0287] The electron transport layer may include at least one selected from BCP, Bphen, Alq₃, BALq, TAZ, and NTAZ.





[0288] In some embodiments, the electron transport layer may include at least one compound selected from a compound represented by Formula 601 and a compound represented by Formula 602:



Formula 601

[0289] In Formula 601,

[0290] Ar_{601} may be selected from:

[0291] a naphthalene, a heptalene, a fluorene, a spiro-fluorene, a benzofluorene, a dibenzofluorene, a phenalene, a phenanthrene, an anthracene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a naphthacene, a picene, a perylene, a pentaphene, and an indenoanthracene; and

[0292] a naphthalene, a heptalene, a fluorene, a spiro-fluorene, a benzofluorene, a dibenzofluorene, a phenalene, a phenanthrene, an anthracene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a naphthacene, a picene, a perylene, a pentaphene, and an indenoanthracene, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a $\text{C}_1\text{-C}_{60}$ alkyl group, a $\text{C}_2\text{-C}_{60}$ alkenyl group, a $\text{C}_2\text{-C}_{60}$ alkynyl group, a $\text{C}_1\text{-C}_{60}$ alkoxy group, a $\text{C}_3\text{-C}_{10}$ cycloalkyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkyl group, a $\text{C}_3\text{-C}_{10}$ cycloalkenyl group, a $\text{C}_1\text{-C}_{10}$ heterocycloalkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, a $\text{C}_6\text{-C}_{60}$ aryloxy group, a $\text{C}_6\text{-C}_{60}$ arylthio group, a $\text{C}_1\text{-C}_{60}$ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, a terphenyl group, and —Si(Q_{301})(Q_{302})(Q_{303}), wherein Q_{301} to Q_{303} may be each independently selected from hydrogen, a $\text{C}_1\text{-C}_{60}$ alkyl group, a $\text{C}_2\text{-C}_{60}$ alkenyl group, a $\text{C}_6\text{-C}_{60}$ aryl group, and a $\text{C}_1\text{-C}_{60}$ heteroaryl group.

[0293] L_{601} may be the same as described herein in connection with L_{201} ;

[0294] E_{601} may be selected from:

[0295] a pyrrolyl group, a thiophenyl group, a furanyl 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 isoindolyl group, an

indolyl group, an indazolyl group, a purinyl 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 carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group; and

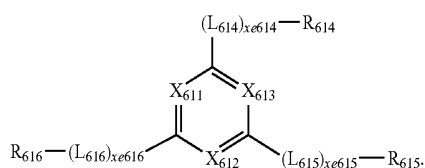
[0296] a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl 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 carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a $\text{C}_1\text{-C}_{20}$ alkyl group, a $\text{C}_1\text{-C}_{20}$ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a 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-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 naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, 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 isoindolyl group, an indolyl group, an indazolyl group, a purinyl 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 carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl

group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group,

[0297] xe1 may be selected from 0, 1, 2, and 3, and

[0298] xe2 may be selected from 1, 2, 3, and 4.

Formula 602



[0299] In Formula 602,

[0300] X_{611} may be selected from N and $C-(L_{611})_{xe611}-R_{611}$; X_{612} may be selected from N and $C-(L_{612})_{xe612}-R_{612}$; X_{613} may be selected from N and $C-(L_{613})_{xe613}-R_{613}$; and at least one selected from X_{611} to X_{613} may be N,

[0301] L_{611} to L_{616} may each independently be the same as described herein in connection with L_{201} ;

[0302] R_{611} to R_{616} may each independently be selected from:

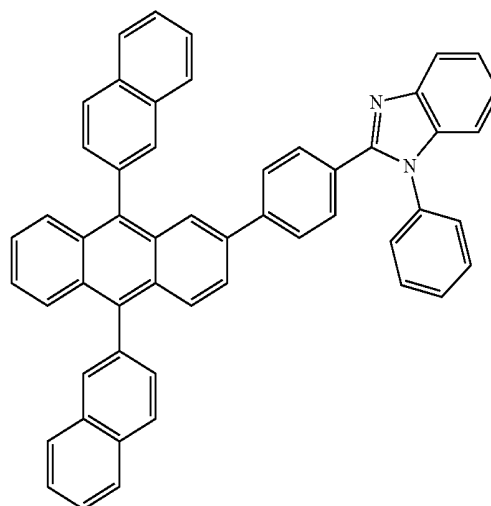
[0303] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

[0304] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, and

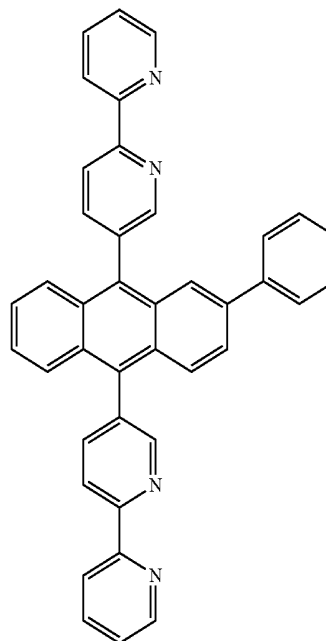
[0305] xe611 to xe616 may each independently be selected from 0, 1, 2, and 3.

[0306] The compound represented by Formula 601 and the compound represented by Formula 602 may each independently be selected from Compounds ET1 to ET15:

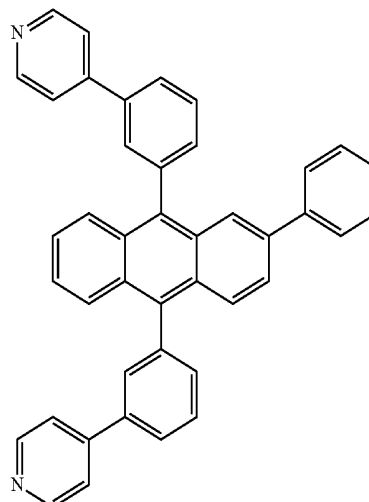
ET1



ET2

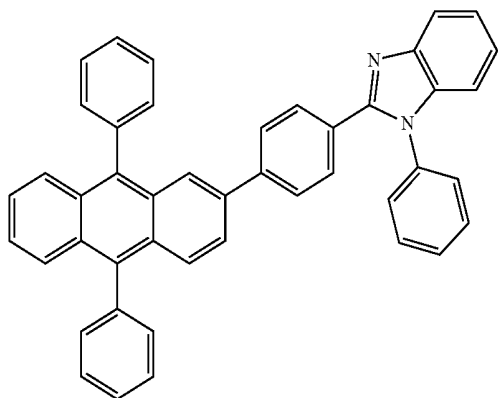


ET3



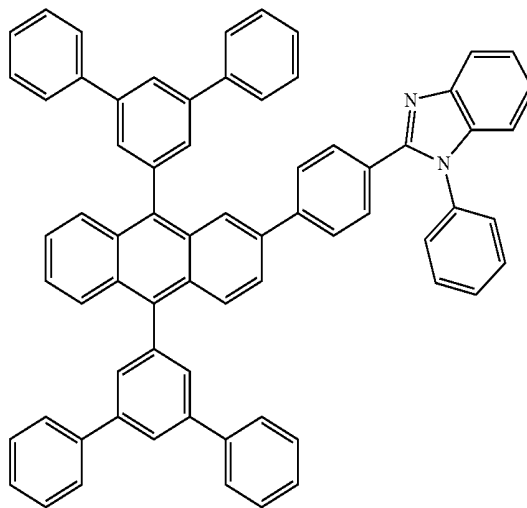
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ET4

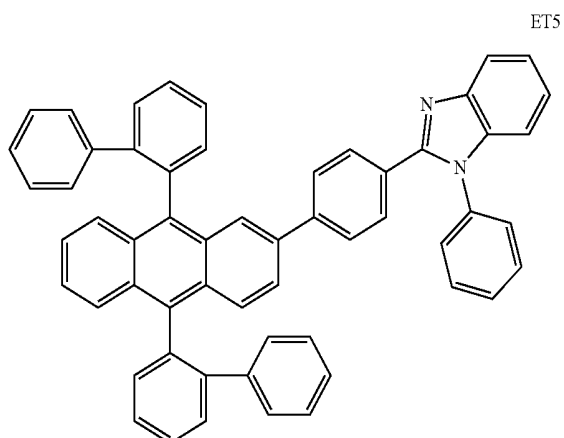


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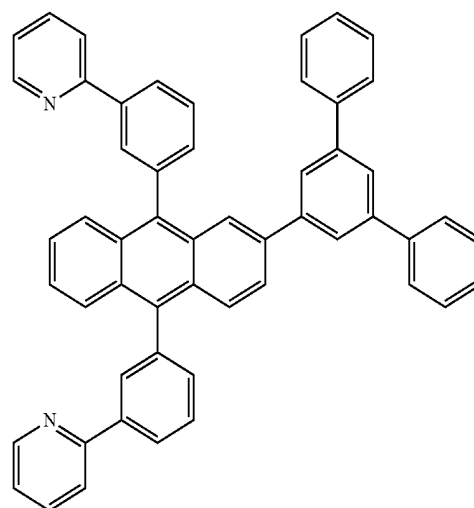
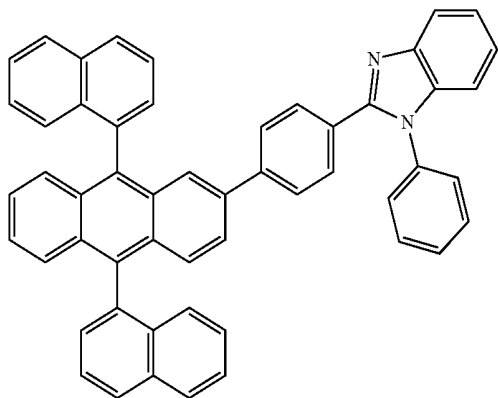
ET7



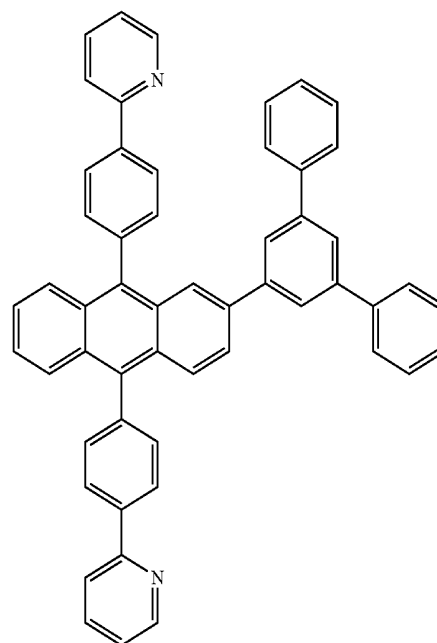
ET8



ET6

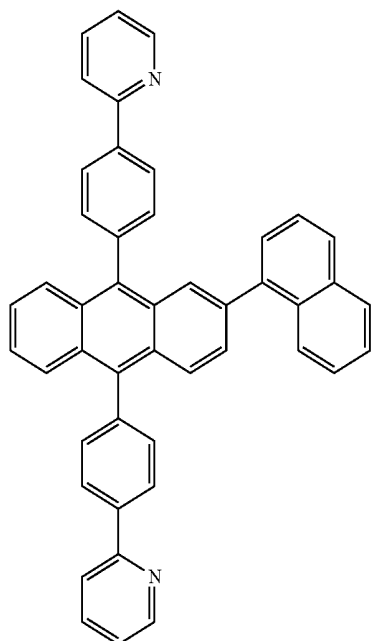


ET9



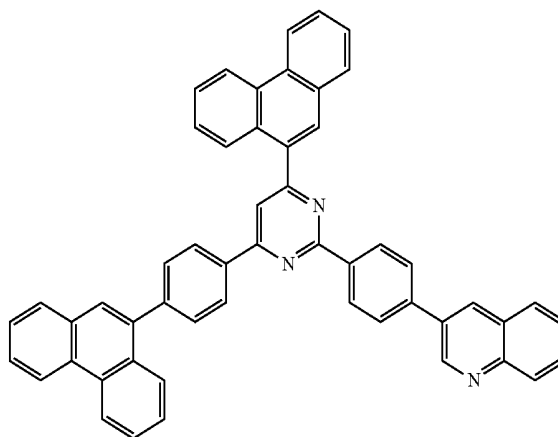
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ET10



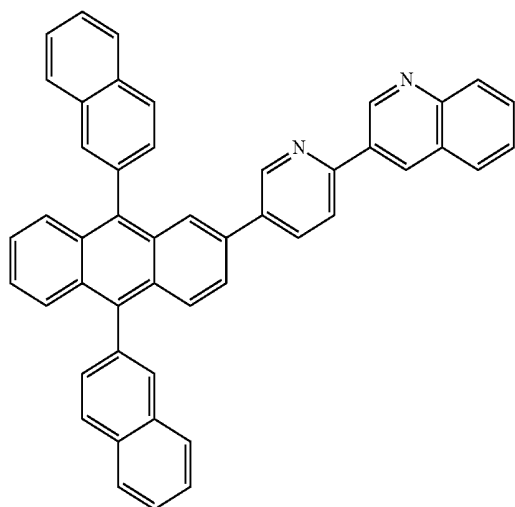
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ET13

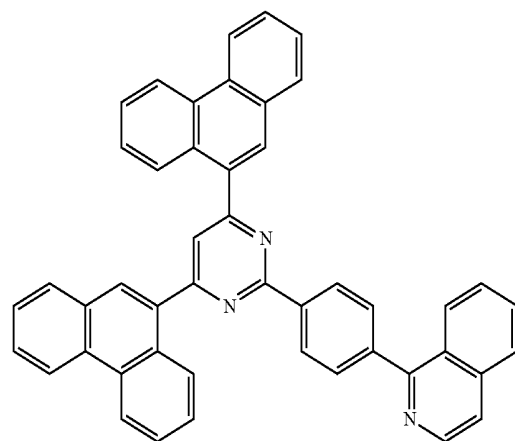


ET14

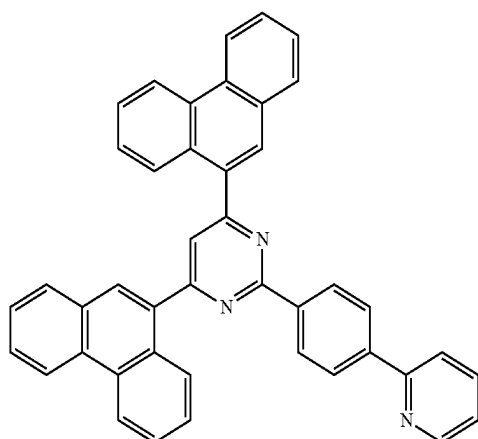
ET11



ET15



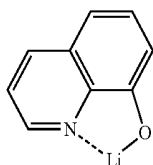
ET12



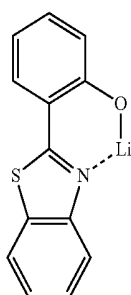
[0307] The thickness of the electron transport layer may be about 100 Å to about 1000 Å, and in some embodiments, about 150 Å to about 500 Å. When the thickness of the electron transport layer is within this range, excellent electron transport characteristics may be obtained without a substantial increase in driving voltage.

[0308] The electron transport layer may further include a metal-containing material in addition to the materials described above.

[0309] The metal-containing material may include a Li complex. The Li complex may include, for example, Compound ET-D1 (lithium quinolate or LiQ) and/or ET-D2.



ET-D1



ET-D2

[0310] The electron transport region may include an electron injection layer that facilitates electron injection from the second electrode **190**.

[0311] The electron injection layer may be formed on the electron transport layer using one or more suitable methods, such as vacuum deposition, spin coating, casting, an LB method, ink-jet printing, laser printing, and/or LITI. When the electron injection layer is formed by vacuum deposition or spin coating, vacuum deposition and coating conditions for the electron injection layer may be similar to the vacuum deposition and coating conditions for the hole injection layer.

[0312] The electron injection layer may include at least one selected from LiF, NaCl, CsF, Li₂O, BaO, and LiQ.

[0313] The thickness of the electron injection layer may be about 1 Å to about 100 Å, and in some embodiments, about 3 Å to about 90 Å. When the thickness of the electron injection layer is within this range, excellent electron injection characteristics may be obtained without a substantial increase in driving voltage.

[0314] The second electrode **190** may be on the organic layer **150**. The second electrode **190** may be a cathode that is an electron injection electrode. In this regard, a material for forming the second electrode **190** may be a material having a low work function, for example, a metal, an alloy, an electrically conductive compound, and/or a mixture thereof. Non-limiting examples of the material for forming the second electrode **190** may include lithium (Li), magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), and/or magnesium-silver (Mg—Ag). In some embodiments, the material for forming the second electrode **190** may be ITO and/or IZO. The second electrode **190** may be a reflective electrode, a semi-transmissive electrode, and/or a transmissive electrode.

[0315] Hereinbefore the organic light-emitting device has been described with reference to FIG. 1, but embodiments of the present disclosure are not limited thereto.

[0316] The term “C₁-C₆₀ alkyl group”, as used herein, may refer to a linear or branched aliphatic hydrocarbon

monovalent group having 1 to 60 carbon atoms. Non-limiting examples thereof may include a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, a pentyl group, an iso-amyl group, and a hexyl group. The term “C₁-C₆₀ alkylene group”, as used herein, may refer to a divalent group having substantially the same structure as the C₁-C₆₀ alkyl group.

[0317] The term “C₁-C₆₀ alkoxy group”, as used herein, may refer to a monovalent group represented by —O-A₁₀₁ (where A₁₀₁ is a C₁-C₆₀ alkyl group). Non-limiting examples thereof may include a methoxy group, an ethoxy group, and an isopropoxy group.

[0318] The term “C₂-C₆₀ alkenyl group”, as used herein, may refer to a hydrocarbon group having at least one carbon-carbon double bond in the body (e.g., the middle) or at the terminus of the C₂-C₆₀ alkyl group. Non-limiting examples thereof may include an ethenyl group, a propenyl group, and a butenyl group. The term “C₂-C₆₀ alkenylene group”, as used herein, may refer to a divalent group having substantially the same structure as the C₂-C₆₀ alkenyl group.

[0319] The term “C₂-C₆₀ alkynyl group”, as used herein, may refer to a hydrocarbon group having at least one carbon-carbon triple bond in the body (e.g., the middle) or at the terminus of the C₂-C₆₀ alkyl group. Non-limiting examples thereof may include an ethynyl group and a propynyl group. The term “C₂-C₆₀ alkynylene group”, as used herein, may refer to a divalent group having the same structure as the C₂-C₆₀ alkynyl group.

[0320] The term “C₃-C₁₀ cycloalkyl group”, as used herein, may refer to a monovalent monocyclic saturated hydrocarbon group including 3 to 10 carbon atoms. Non-limiting examples thereof may include a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. The term “C₃-C₁₀ cycloalkylene group”, as used herein, may refer to a divalent group having substantially the same structure as the C₃-C₁₀ cycloalkyl group.

[0321] The term “C₁-C₁₀ heterocycloalkyl group”, as used herein, may refer to a monovalent monocyclic group including at least one heteroatom selected from N, O, P, and S as a ring-forming atom and 1 to 10 carbon atoms. Non-limiting examples thereof may include a tetrahydrofuran group and a tetrahydrothiophene group. The term “C₁-C₁₀ heterocycloalkylene group”, as used herein, may refer to a divalent group having substantially the same structure as the C₁-C₁₀ heterocycloalkyl group.

[0322] The term “C₃-C₁₀ cycloalkenyl group”, as used herein, may refer to a monovalent monocyclic group that has 3 to 10 carbon atoms and at least one double bond in its ring, and is not aromatic. Non-limiting examples thereof may include a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. The term “C₃-C₁₀ cycloalkenylene group”, as used herein, may refer to a divalent group having the same structure as the C₃-C₁₀ cycloalkenyl group.

[0323] The term “C₁-C₁₀ heterocycloalkenyl group”, as used herein, may refer to a monovalent monocyclic group including at least one heteroatom selected from N, O, P, and S as a ring-forming atom, 1 to 10 carbon atoms, and at least one double bond in its ring. Non-limiting examples of the C₁-C₁₀ heterocycloalkenyl group may include a 2,3-dihydrofuran group and a 2,3-dihydrothiophene group. The term “C₁-C₁₀ heterocycloalkenylene group”, as used herein, may refer to a divalent group having substantially the same structure as the C₁-C₁₀ heterocycloalkenyl group.

[0324] The term “C₆₀-C₆₀ aryl group”, as used herein, may refer to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms, and the term “C₆₀-C₆₀ arylene group”, as used herein, may refer to a divalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms. Non-limiting examples of the C₆₀-C₆₀ 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 C₆₀-C₆₀ aryl group and the C₆₀-C₆₀ arylene group each include a plurality of rings, the rings may be fused to each other.

[0325] The term “C₁-C₆₀ heteroaryl group”, as used herein, may refer to a monovalent group having a carbocyclic aromatic system including at least one heteroatom selected from N, O, P, and S as a ring-forming atom and 1 to 60 carbon atoms. The term “C₁-C₆₀ heteroarylene group”, as used herein, may refer to a divalent group having a carbocyclic aromatic system including at least one heteroatom selected from N, O, P, and S as a ring-forming atom and 1 to 60 carbon atoms. Non-limiting examples of the C₁-C₆₀ 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 C₁-C₆₀ heteroaryl group and the C₁-C₆₀ heteroarylene group each include a plurality of rings, the rings may be fused to each other.

[0326] The term “C₆₀-C₆₀ aryloxy group”, as used herein, may refer to a group represented by —O-A₁₀₂ (where A₁₀₂ is the C₆₀-C₆₀ aryl group). The term “C₆₀-C₆₀ arylthio group”, as used herein, may refer to a group represented by —S-A₁₀₃ (where A₁₀₃ is the C₆₀-C₆₀ aryl group).

[0327] The term “monovalent non-aromatic condensed polycyclic group”, as used herein, may refer to a monovalent group that has two or more rings condensed to each other, and has only carbon atoms as ring-forming atoms (for example, the number of carbon atoms may be in a range of 8 to 60), wherein the molecular structure as a whole is non-aromatic in the entire molecular structure (e.g., the entire group is not aromatic). A non-limiting example of the monovalent non-aromatic condensed polycyclic group is a fluorenyl group. The term “divalent non-aromatic condensed polycyclic group”, as used herein, may refer to a divalent group having substantially the same structure as the monovalent non-aromatic condensed polycyclic group.

[0328] The term “monovalent non-aromatic condensed heteropolycyclic group”, as used herein, may refer to a monovalent group that has two or more rings condensed to each other, and has a heteroatom selected from N, O, P, and S, other than carbon atoms (for example, the number of carbon atoms may be in a range of 1 to 60), as ring-forming atoms, wherein the molecular structure as a whole is non-aromatic in the entire molecular structure (e.g., the entire group is not aromatic). A non-limiting example of a monovalent non-aromatic condensed heteropolycyclic group may include a carbazoyl group. The term “divalent non-aromatic condensed hetero-polycyclic group”, as used herein, may refer to a divalent group having substantially the same structure as the monovalent non-aromatic condensed hetero-polycyclic group.

[0329] Throughout the specification, at least one of the substituents of the substituted triazine, substituted vinylene carbonate, substituted thiophene, substituted azulene, substituted naphthalene, substituted anthracene, substituted pyrene, substituted C₃-C₁₀ cycloalkylene group, substituted

C₁-C₁₀ heterocycloalkylene group, substituted C₃-C₁₀ cycloalkenylene group, substituted C₁-C₁₀ heterocycloalkenylene group, substituted C₆-C₆₀ arylene group, substituted C₁-C₆₀ heteroarylene group, substituted divalent non-aromatic condensed polycyclic group, substituted divalent non-aromatic condensed heteropolycyclic group, substituted C₁-C₆₀ alkyl group, substituted C₂-C₆₀ alkenyl group, substituted C₂-C₆₀ alkynyl group, substituted C₁-C₆₀ alkoxy group, substituted C₃-C₁₀ cycloalkyl group, substituted C₁-C₁₀ heterocycloalkyl group, substituted C₃-C₁₀ cycloalkenyl group, substituted C₁-C₁₀ heterocycloalkenyl group, substituted C₆-C₆₀ aryl group, substituted C₆-C₆₀ aryloxy group, substituted C₆-C₆₀ arylthio group, substituted C₁-C₆₀ heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from:

[0330] deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group;

[0331] a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, a terphenyl group, —N(Q₁₁)(Q₁₂), —Si(Q₁₃)(Q₁₄)(Q₁₅), and —B(Q₁₆)(Q₁₇);

[0332] a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group;

[0333] a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy

group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, a terphenyl group, —N(Q₂₁)(Q₂₂), —Si(Q₂₃)(Q₂₄)(Q₂₅) and —B(Q₂₆)(Q₂₇), and

[0334] —N(Q₃₁)(Q₃₂), —Si(Q₃₃)(Q₃₄)(Q₃₅), and —B(Q₃₆)(Q₃₇),

[0335] wherein Q₁₁ to Q₁₇, Q₂₁ to Q₂₇, and Q₃₁ to Q₃₇ may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

[0336] In some embodiments, at least one of the substituents of the substituted triazine, substituted vinylene carbonate, substituted thiophene, substituted azulene, substituted naphthalene, substituted anthracene, substituted pyrene, substituted C₃-C₁₀ cycloalkylene group, substituted C₁-C₁₀ heterocycloalkylene group, substituted C₃-C₁₀ cycloalkenylene group, substituted C₁-C₁₀ heterocycloalkenylene group, substituted C₆-C₆₀ arylene group, substituted C₁-C₆₀ heteroarylene group, substituted divalent non-aromatic condensed polycyclic group, substituted divalent non-aromatic condensed heteropolycyclic group, substituted C₁-C₆₀ alkyl group, substituted C₂-C₆₀ alkenyl group, substituted C₂-C₆₀ alkynyl group, substituted C₁-C₆₀ alkoxy group, substituted C₃-C₁₀ cycloalkyl group, substituted C₁-C₁₀ heterocycloalkyl group, substituted C₃-C₁₀ cycloalkenyl group, substituted C₁-C₁₀ heterocycloalkenyl group, substituted C₆-C₆₀ aryl group, substituted C₆-C₆₀ aryloxy group, substituted C₆-C₆₀ arylthio group, substituted C₁-C₆₀ heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from:

[0337] deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazine group, a hydrazine group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group;

[0338] a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazine group, a hydrazine group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-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 naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, 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 isoindolyl group, an indolyl group, an indazolyl group, a purinyl 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 carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranlyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranlyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, —N(Q₁₁)(Q₁₂), —Si(Q₁₃)(Q₁₄)(Q₁₅), and —B(Q₁₆)(Q₁₇);

[0339] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-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 naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, 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 isoindolyl group, an indolyl group, an indazolyl group, a purinyl 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 carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranlyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranlyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group;

[0340] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyre-

nyl group, a chrysenyl group, a naphthacenylyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, 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 isoindolyl group, an indolyl group, an indazolyl group, a purinyl 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 carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranlyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranlyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60} alkynyl group, a C_1 - C_{60} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-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 naphthacenylyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, 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 isoindolyl group, an indolyl group, an indazolyl group, a purinyl 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 carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranlyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranlyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group.

[0341] —N(Q_{31})(Q_{32}), —Si(Q_{33})(Q_{34})(Q_{35}), and —B(Q_{36})(Q_{37}),

[0342] wherein Q_{11} to Q_{17} , Q_{21} to Q_{27} , and Q_{31} to Q_{37} may each independently be selected from hydrogen, deuterium,

—F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60} alkynyl group, a C_1 - C_{60} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-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 naphthacenylyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, 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 isoindolyl group, an indolyl group, an indazolyl group, a purinyl 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 carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranlyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranlyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group.

[0343] The term “Ph” as used herein may refer to a phenyl group; the term “Me” may refer to a methyl group; the term “Et” may refer to an ethyl group; and the term “ter-Bu” or “Bu” may refer to a tert-butyl group.

[0344] The term “biphenyl group” may refer to a monovalent group in which two benzene rings are bound to each other via a single bond. The term “terphenyl group” may refer to a monovalent group in which three benzene rings are bound to each other via two single bonds.

[0345] Hereinafter, an organic light-emitting device according to an embodiment of the present disclosure will be described in more detail with reference to Examples.

EXAMPLE

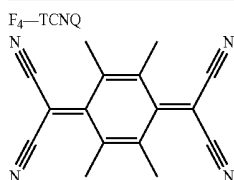
Evaluation Example 1

[0346] Molecular simulations were performed on Compounds 1 to 5, F₄-TCNQ, and Compounds A to C using a Vienna ab-initio simulation package (VASP). The ionization potential (IP) and electron affinity (EA) were calculated for each molecule, and the results thereof are shown in Table 1.

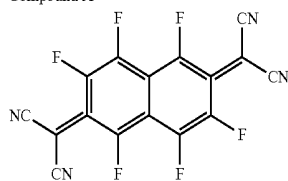
[0347] The ionization potential (IP) and electron affinity (EA) of a Reference Example, HT 21, are shown as well:

TABLE 1

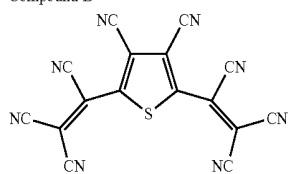
Material		Ionization potential (eV)	Electron affinity (eV)
Example 1	Compound 1	8.62	4.95
Example 2	Compound 2	8.73	4.60
Example 3	Compound 3	8.42	4.80
Example 4	Compound 4	7.78	4.73
Example 5	Compound 5	8.14	4.71
Comparative Example 1	F ₄ -TCNQ	9.34	4.01
Comparative Example 2	Compound A	8.76	4.19
Comparative Example 3	Compound B	7.92	3.86
Comparative Example 4	Compound C	9.66	4.42
Reference Example	HT21	5.71	0.94



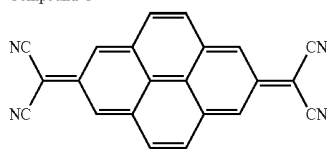
Compound A



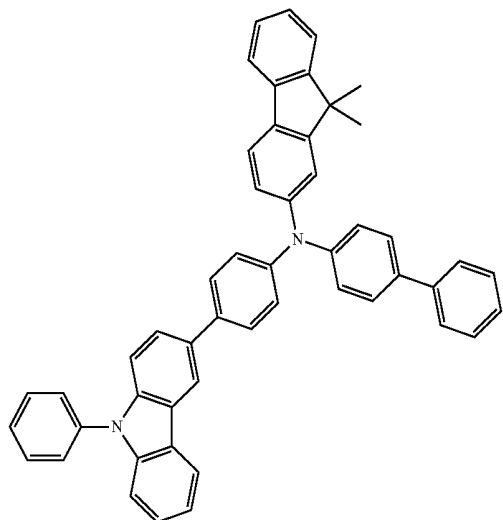
Compound B



Compound C



HT21



[0348] Referring to Table 1, Compounds 1 to 5 of Examples 1 to 5 were found to have high electron affinities compared to the compounds used in Comparative Examples 1 to 4.

Evaluation Example 2

[0349] An electronegativity equalization model (EEM) was used to simulate the interface barrier between an anode and a PHTL (p-dopant doped hole transport layer). The hole injection barriers (HIB) at an interface between an indium tin oxide (ITO) anode and PHTL were calculated according to Equation (1) for samples in which the matrix was HT21, and the p-dopant was selected from the compounds of Examples 1 to 5 and the compounds of Comparative Examples 1 to 4. Equation (1) is derived from the electronegativity equalization principle, which states that the electronegativity (χ) is equalized throughout (e.g., evenly distributed between) adjacent atoms or molecules. The results thereof are shown in FIG. 3:

$$HIB = \eta^{Org} + \frac{(\chi^{Org} - \chi^M)}{(1 + \eta^M / \eta^{Org})}. \quad \text{Equation (1)}$$

[0350] In Equation (1), χ indicates the electronegativity, and η indicates the chemical hardness (e.g., of a material). The superscripts M and Org indicate a metal (e.g., an anode material), and an organic material (e.g., an HTL material), respectively. χ and η may be calculated from the ionization potential (IP) and the electron affinity (EA) using Equation (2):

$$\chi = \frac{IP + EA}{2}, \eta = \frac{IP - EA}{2}. \quad \text{Equation (2)}$$

[0351] Using Equation (2) for the ITO anode, χ^M was 5.85 eV and η^M was 1.7 eV.

[0352] χ and η of the PHTL may be calculated from the IP and the EA of a hole transport layer material and a p-dopant. In this calculation, the molar ratio of p-dopant may also be a variable. The equation to calculate χ and η of the PHTL taking into account the molar ratio of p-dopant may be as follows:

$$N^H \exp \left[-\frac{\chi^{PHTL} - IP^H}{kT} \right] = \quad \text{Equation (3)}$$

$$(N^H - N^D) \exp \left[-\frac{EA^H - IP^H}{2kT} \right] + N^D \exp \left[-\frac{EA^D - IP^H}{2kT} \right].$$

$$\chi^{PHTL} = IP^H - kT \log \left\{ \exp \left[-\frac{EA^H - IP^H}{2kT} \right] - \quad \text{Equation (4)}$$

$$\frac{N^D}{N^H} \left(\exp \left[-\frac{EA^H - IP^H}{2kT} \right] - \exp \left[-\frac{EA^D - IP^H}{2kT} \right] \right) \right\}.$$

$$\eta^{PHTL} = IP^H - \chi^{PHTL}. \quad \text{Equation (5)}$$

[0353] In Equations (3) to (5), N is the molar ratio, k is the Boltzmann constant, and T is the temperature (e.g., room temperature). The subscript H indicates an HTL material, and D indicates a p-dopant.

[0354] Using Equations (3) and (4) for HT21, EA^H was 0.94 eV, and IP^H was 5.71 eV.

[0355] By substituting the values of χ^{PHTL} and η^{PHTL} calculated using Equations (4) and (5) into χ^{Org} and η^{Org} of Equation (1), respectively, the energy of the hole injection barrier (HIB) at an interface between the anode and the PHTL according to the molar ratio of p-dopant may be calculated, as shown in FIG. 3.

[0356] Referring to FIG. 3, the organic light-emitting devices of Examples 1 to 5 were calculated to have lower HIBs than the organic light-emitting devices of Comparative Examples 1 to 4.

[0357] It should be understood that example embodiments described herein should be considered in a descriptive sense only and not for purposes of limitation. Descriptions of features or aspects within each example embodiment should typically be considered as being available for other similar features or aspects in other example embodiments.

[0358] As used herein, the use of “may” when describing embodiments of the present disclosure refers to “one or more embodiments of the present disclosure”. In addition, as used herein, the terms “use”, “using”, and “used” may be considered synonymous with the terms “utilize”, “utilizing”, and “utilized”, respectively.

[0359] As used herein, the terms “substantially”, “about”, and similar terms are used as terms of approximation and not as terms of degree, and are intended to account for the inherent deviations in measured or calculated values that would be recognized by those of ordinary skill in the art.

[0360] Also, any numerical range recited herein is intended to include all sub-ranges of the same numerical precision subsumed within the recited range. For example, a range of “1.0 to 10.0” is intended to include all subranges between (and including) the recited minimum value of 1.0 and the recited maximum value of 10.0, that is, having a minimum value equal to or greater than 1.0 and a maximum value equal to or less than 10.0, such as, for example, 2.4 to 7.6. Any maximum numerical limitation recited herein is intended to include all lower numerical limitations subsumed therein and any minimum numerical limitation recited in this specification is intended to include all higher numerical limitations subsumed therein. Accordingly, Applicant reserves the right to amend this specification, including the claims, to expressly recite any sub-range subsumed within the ranges expressly recited herein.

[0361] While one or more example embodiments have been described with reference to the drawings, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope as defined by the following claims and equivalents thereof.

What is claimed is:

1. A dibenzoborole-based compound represented by Formula 1:



Formula 1

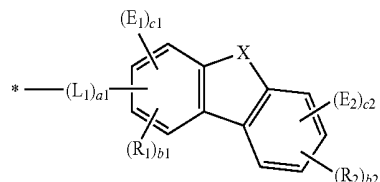
wherein, in Formula 1,

A_1 is selected from a substituted or unsubstituted triazine, a substituted or unsubstituted vinylenecarbonate, a substituted or unsubstituted thiophene, a substituted or unsubstituted azulene, a substituted or unsubstituted naphthalene, a substituted or unsubstituted anthracene, and a substituted or unsubstituted pyrene,

$n1$ is an integer selected from 1 to 10, and when $n1$ is 2 or greater, each A_2 moiety is independently selected from below-described groups,

A_2 is represented by Formula 2:

Formula 2



wherein, in Formula 2,

X is selected from $B(E_{31})$ and $B(R_{31})$,

L_1 is selected from a substituted or unsubstituted C_3 - C_{10} cycloalkylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3 - C_{10} cycloalkenylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6 - C_{60} arylene group, a substituted or unsubstituted C_1 - C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

$a1$ is selected from 0 and 1,

E_1 , E_2 , and E_{31} are each an electron withdrawing group, $c1$ is an integer selected from 0 to 3, $c2$ is an integer selected from 0 to 4, and a sum of $c1$ and $c2$ is 1 or more,

R_1 , R_2 , and R_{31} are each independently selected from hydrogen, deuterium, a hydroxyl group, an amino group, an imidino group, a hydrazine group, a hydrazone 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, $-N(Q_1)(Q_2)$, $-Si(Q_3)(Q_4)(Q_5)$, and $-B(Q_6)(Q_7)$,

$b1$ is an integer selected from 0 to 3, and $b2$ is an integer selected from 0 to 4,

at least one substituent of the substituted triazine, substituted vinylenecarbonate, substituted thiophene, substituted azulene, substituted naphthalene, substituted anthracene, substituted pyrene, substituted C_3 - C_{10} cycloalkylene group, substituted C_1 - C_{10} heterocycloalkylene group, substituted C_3 - C_{10} cycloalkenylene group, substituted C_1 - C_{10} heterocycloalkenylene group, substituted C_6 - C_{60} arylene group, substituted

C₁-C₆₀ heteroarylene group, substituted divalent non-aromatic condensed polycyclic group, substituted divalent non-aromatic condensed heteropolycyclic group, substituted C₁-C₆₀ alkyl group, substituted C₂-C₆₀ alkenyl group, substituted C₂-C₆₀ alkynyl group, substituted C₁-C₆₀ alkoxy group, substituted C₃-C₁₀ cycloalkyl group, substituted C₁-C₁₀ heterocycloalkyl group, substituted C₃-C₁₀ cycloalkenyl group, substituted C₁-C₁₀ heterocycloalkenyl group, substituted C₆-C₆₀ aryl group, substituted C₆-C₆₀ aryloxy group, substituted C₆-C₆₀ arylthio group, substituted C₁-C₆₀ heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic condensed heteropolycyclic group is selected from:

deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group;

a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, a terphenyl group, —N(Q₁₁)(Q₁₂), —Si(Q₁₃)(Q₁₄)(Q₁₅), and —B(Q₁₆)(Q₁₇);

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

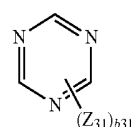
a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀

heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, a terphenyl group, —N(Q₂₁)(Q₂₂), —Si(Q₂₃)(Q₂₄)(Q₂₅) and —B(Q₂₆)(Q₂₇), and

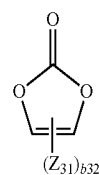
—N(Q₃₁)(Q₃₂), —Si(Q₃₃)(Q₃₄)(Q₃₅), and —B(Q₃₆)(Q₃₇),

wherein Q₁ to Q₇, Q₁₁ to Q₁₇, Q₂₁ to Q₂₇, and Q₃₁ to Q₃₇ are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, and * indicates a binding site to A₁.

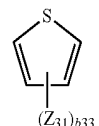
2. The dibenzoborole-based compound of claim 1, wherein, in Formula 1, A₁ is selected from Formulae 1A to 7A:



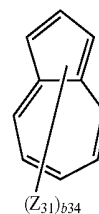
1A



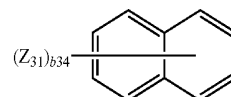
2A



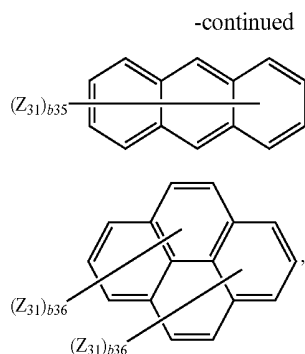
3A



4A



5A



6A

7A

wherein, in Formulae 1A to 7A,

Z_{31} and Z_{32} are each independently selected from:

a binding site to A_2 ;

hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60} alkynyl group, and a C_1 - C_{60} alkoxy group;

a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60} alkynyl group, and a C_1 - C_{60} alkoxy group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $-N(Q_{11})(Q_{12})$, $-Si(Q_{13})(Q_{14})(Q_{15})$, and $-B(Q_{16})(Q_{17})$,

a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60} alkynyl group, a C_1 - C_{60} alkoxy group, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60}

aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $-N(Q_{21})(Q_{22})$, $-Si(Q_{23})(Q_{24})(Q_{25})$, and $-B(Q_{26})(Q_{27})$, and

$-N(Q_{31})(Q_{32})$, $-Si(Q_{33})(Q_{34})(Q_{35})$, and $-B(Q_{36})(Q_{37})$,

wherein Q_{11} to Q_{17} , Q_{21} to Q_{27} , and Q_{31} to Q_{37} are each independently selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60} alkynyl group, a C_1 - C_{60} alkoxy group, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group,

a number of Z_{31} substituents and/or a number of Z_{31} and Z_{32} substituents that are binding sites to A_2 are each n1,

b31 is an integer selected from 1 to 3,

b32 is an integer selected from 1 and 2,

b33 is an integer selected from 1 to 4,

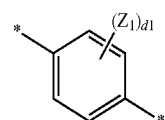
b34 is an integer selected from 1 to 8,

b35 is an integer selected from 1 to 10, and

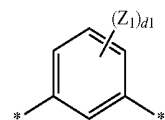
b36 is an integer selected from 1 to 5.

3. The dibenzoborole-based compound of claim 1, wherein, in Formula 1, n1 is an integer selected from 1 to 6.

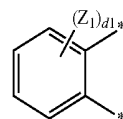
4. The dibenzoborole-based compound of claim 1, wherein, in Formula 2, L_1 is selected from groups represented by Formulae 3-1 to 3-11:



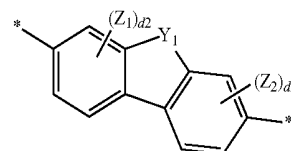
3-1



3-2

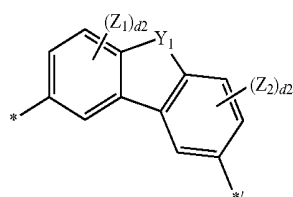


3-3



3-4

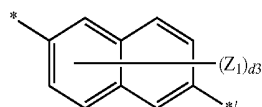
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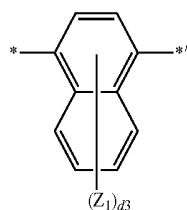
3-5

d1 is an integer selected from 1 to 4, d2 is an integer selected from 1 to 3, d3 is an integer selected from 1 to 6, d4 is an integer selected from 1 to 8, d5 is an integer selected from 1 to 5, and * and *' each indicate a binding site to an adjacent atom.

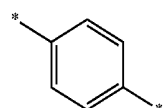
5. The dibenzoborole-based compound of claim 1, wherein, in Formula 2, L_1 is selected from groups represented by Formulae 4-1 to 4-13:



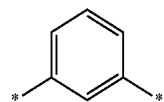
3-6



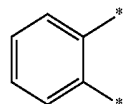
3-7



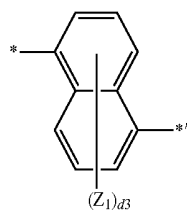
4-1



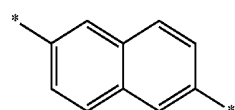
4-2



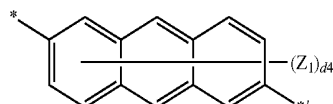
4-3



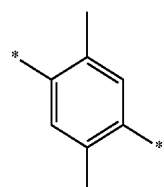
3-8



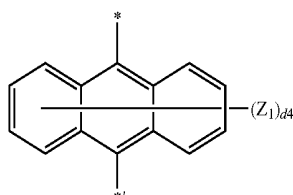
4-4



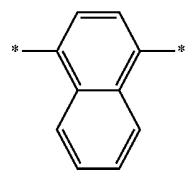
3-9



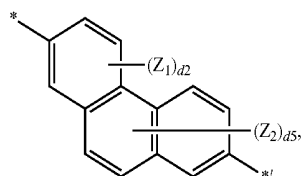
4-5



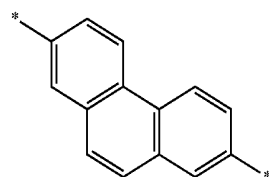
3-10



4-6



3-11

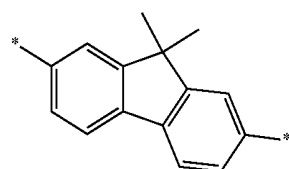


4-7

wherein, in Formulae 3-1 to 3-11,

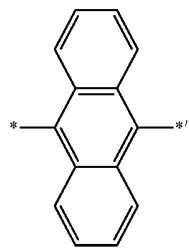
Y_1 is $C(Z_3)(Z_4)$,

Z_1 to Z_4 are each independently selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, and a chrysenyl group,

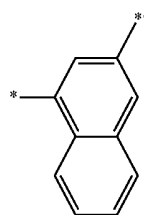


4-8

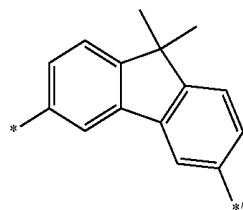
-continued



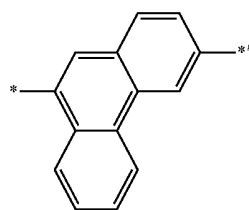
4-9



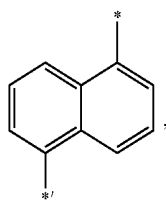
4-10



4-11



4-12



4-13

wherein, in Formulae 4-1 to 4-13, * and *¹ each indicate a binding site to an adjacent atom.

6. The dibenzoborole-based compound of claim 1, wherein, in Formula 2, E₁, E₂, and E₃₁ are each independently selected from —F, —Cl, —Br, —I, —CN, —NO₂, —CF₃, —CCl₃, —C₂F₃, —C₂Cl₃, —C₂(CN)₃, —CBr₃, —C(NO₂)₃, —C₂Br₃, —C₂I₃, —C₂(NO₂)₃, and —PO(Ph)₃.

7. The dibenzoborole-based compound of claim 1, wherein, in Formula 2, X is B(E₃₁), and a sum of c1 and c2 is 4 or greater.

8. The dibenzoborole-based compound of claim 1, wherein, in Formula 2, X is B(E₃₁), c1 is 2, and c2 is 2.

9. The dibenzoborole-based compound of claim 1, wherein,

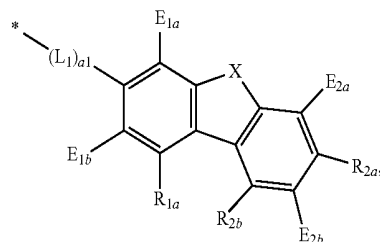
in Formula 2, R₁, R₂, and R₃₁ are each independently selected from hydrogen, deuterium, a hydroxyl group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a C₁-C₂₀ alkyl group, and a C₁-C₂₀ alkoxy group;

a phenyl group and a naphthyl group; and
a phenyl group and a naphthyl group, each substituted with at least one selected from deuterium, a hydroxyl group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, and a naphthyl group.

10. The dibenzoborole-based compound of claim 1, wherein, in Formula 2, b₁ and b₂ are 0.

11. The dibenzoborole-based compound of claim 1, wherein, in Formula 1, A₂ is represented by Formula 2A:

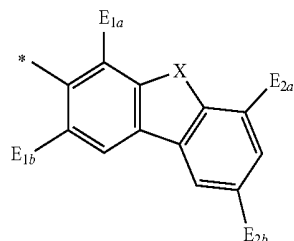
Formula 2A



wherein, in Formula 2A, X, L₁, and a1 are the same as described above, E_{1a} and E_{1b} are the same as E₁, E_{2a} and E_{2b} are the same as E₂, R_{1a} is the same as R₁, and R_{2a} and R_{2b} are the same as R₂.

12. The dibenzoborole-based compound of claim 1, wherein, in Formula 1, A₂ is represented by Formula 2A(1):

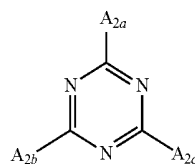
Formula 2A(1)



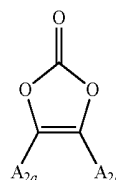
wherein, in Formula 2A(1), X is the same as described above, E_{1a} and E_{1b} are the same as E₁, and E_{2a} and E_{2b} are the same as E₂.

13. The dibenzoborole-based compound of claim 1, represented by one selected from Formulae 1-1 to 1-7:

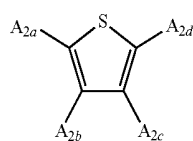
1-1



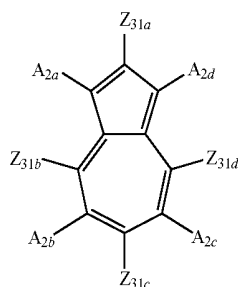
1-2



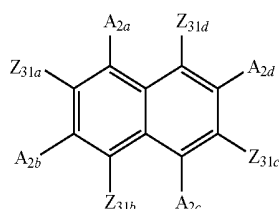
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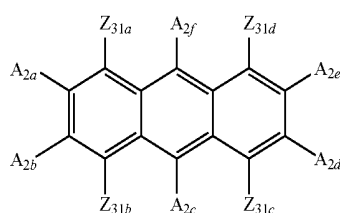
1-3



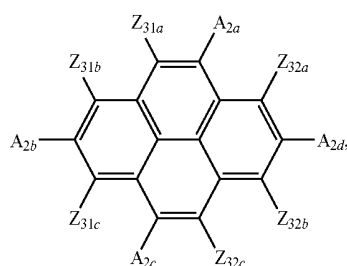
1-4



1-5



1-6



1-7

wherein, in Formulae 1-1 to 1-7, A_{2a} to A_{2f} are the same as A_2 , and Z_{31a} to Z_{31d} and Z_{32a} to Z_{32c} are each independently selected from:

hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60} alkynyl group, and a C_1 - C_{60} alkoxy group;
 a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60} alkynyl group, and a C_1 - C_{60} alkoxy group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof,

thereof, a phosphoric acid group or a salt thereof, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $-N(Q_{11})(Q_{12})$, $-Si(Q_{13})(Q_{14})(Q_{15})$, and $-B(Q_{16})(Q_{17})$,

a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

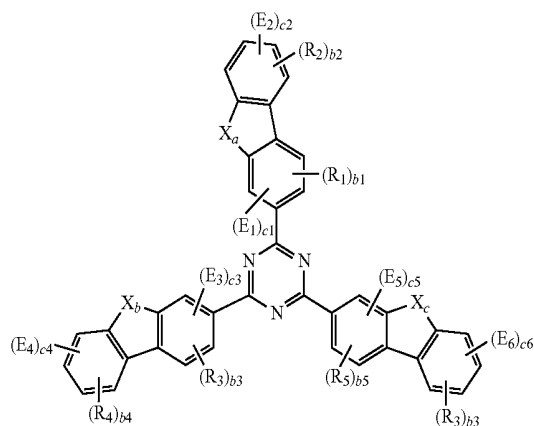
a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60} alkynyl group, a C_1 - C_{60} alkoxy group, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $-N(Q_{21})(Q_{22})$, $-Si(Q_{23})(Q_{24})(Q_{25})$, and $-B(Q_{26})(Q_{27})$, and

$-N(Q_{31})(Q_{32})$, $-Si(Q_{33})(Q_{34})(Q_{35})$, and $-B(Q_{36})(Q_{37})$,

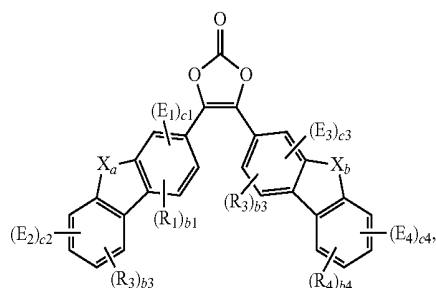
wherein Q_{11} to Q_{17} , Q_{21} to Q_{27} , and Q_{31} to Q_{37} are each independently selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60} alkynyl group, a C_1 - C_{60} alkoxy group, a C_3 - C_{10} cycloalkyl group, a C_1 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_1 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

14. The dibenzoborole-based compound of claim 1, represented by one selected from Formulae 1-1(1) to 1-7(1):

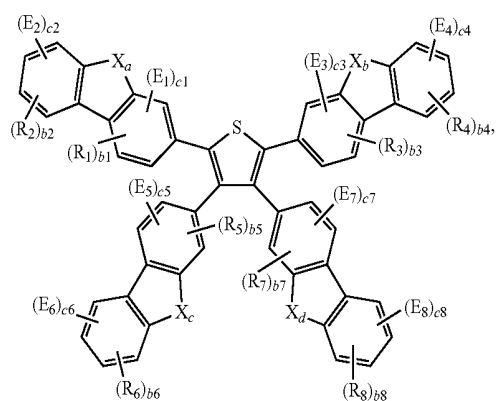
Formula 1-1(1)



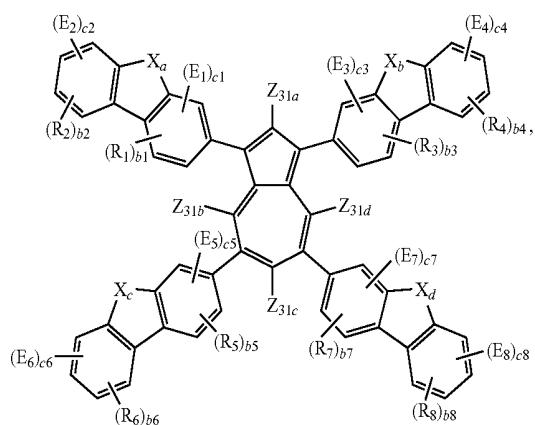
Formula 1-2(1)



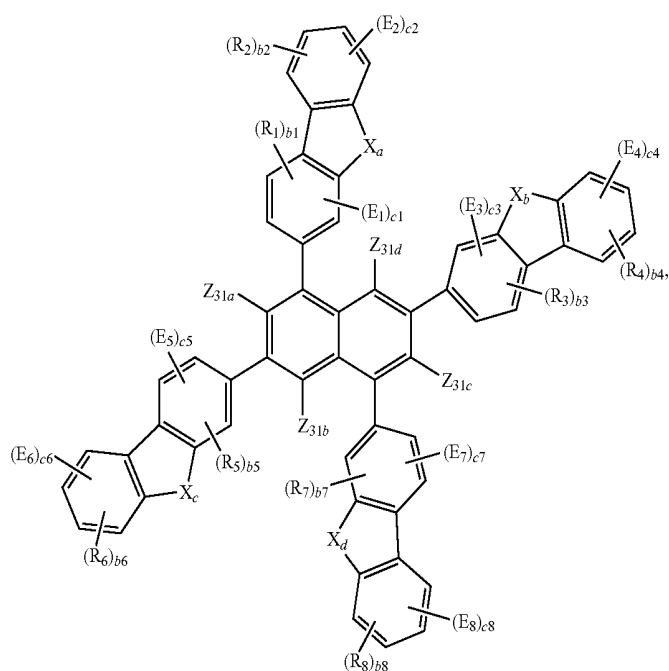
Formula 1-3(1)



Formula 1-4(1)

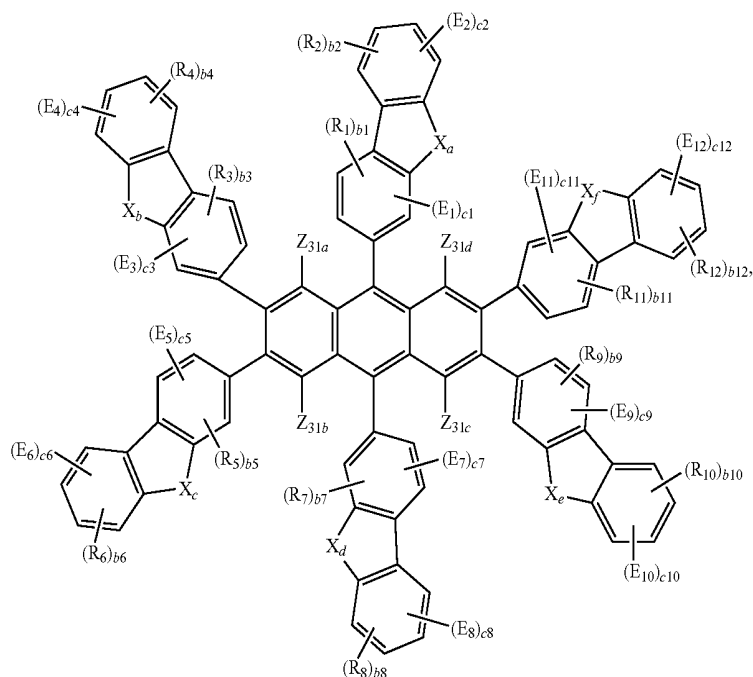


Formula 1-5(1)

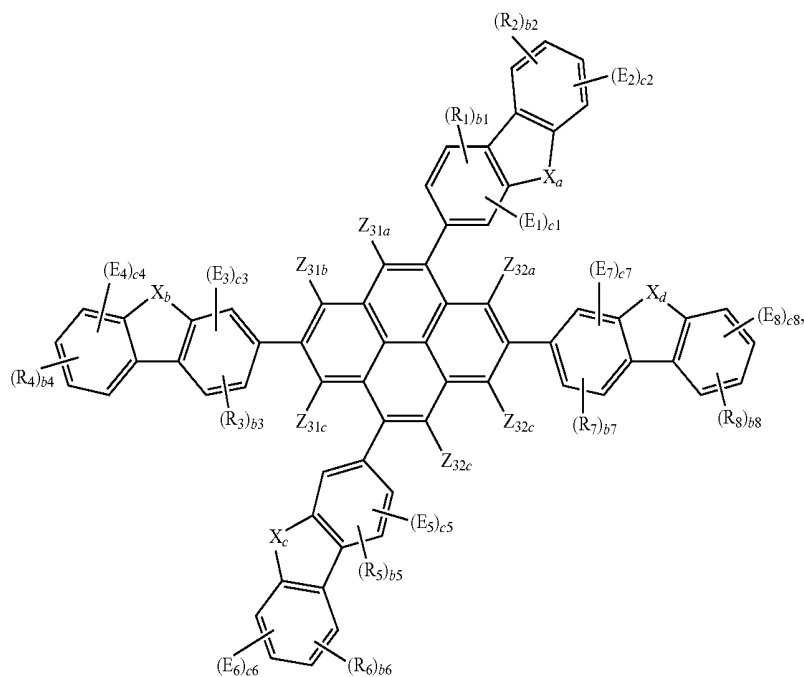


-continued

Formula 1-6(1)



Formula 1-7(1)



wherein, in Formulae 1-1(1) to 1-7(1), E₁, E₂, c₁, c₂, R₁, R₂, b₁, and b₂ are the same as described above, E₃, E₅, E₇, E₉, and E₁₁ are the same as E₁, E₄, E₆, E₈, E₁₀, and E₁₂ are the same as E₂, c₃, c₅, c₇, c₉, and c₁₁ are the same as c₁, c₄, c₆, c₈, c₁₀, and c₁₂ are the same as c₂, R₃, R₅, R₇, R₉, and R₁₁ are the same as R₁, R₄, R₆, R₈, R₁₀, and R₁₂ are the same as R₂, b₃, b₅, b₇, b₉, and b₁₁ are the same as b₁, and b₄, b₆, b₈, b₁₀, and b₁₂ are the same as b₂,

X_a is selected from B(E_{31a}) and B(R_{31a}),

X_b is selected from B(E_{31b}) and B(R_{31b}),

X_c is selected from B(E_{31c}) and B(R_{31c}),

X_d is selected from B(E_{31d}) and B(R_{31d}),

X_e is selected from B(E_{31e}) and B(R_{31e}),

X_f is selected from B(E_{31f}) and B(R_{31f}),

E_{31a} to E_{31f} are the same as E₃₁, R_{31a} to R_{31f} are the same as R₃₁,

Z_{31a} to Z_{31d} and Z_{32a} to Z_{32c} are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt

- thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group;
- a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q₁₁)(Q₁₂), —Si(Q₁₃)(Q₁₄)(Q₁₆), and —B(Q₁₆)(Q₁₇),
- a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;
- a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at

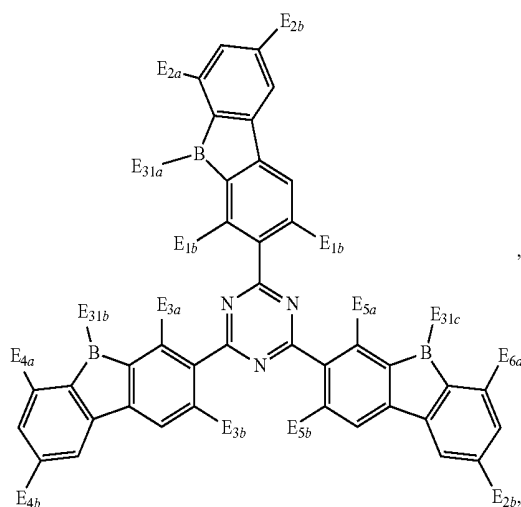
least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q₂₁)(Q₂₂), —Si(Q₂₃)(Q₂₄)(Q₂₆), and —B(Q₂₆)(Q₂₇), and

—N(Q₃₁)(Q₃₂), —Si(Q₃₃)(Q₃₄)(Q₃₆), and —B(Q₃₆)(Q₃₇),

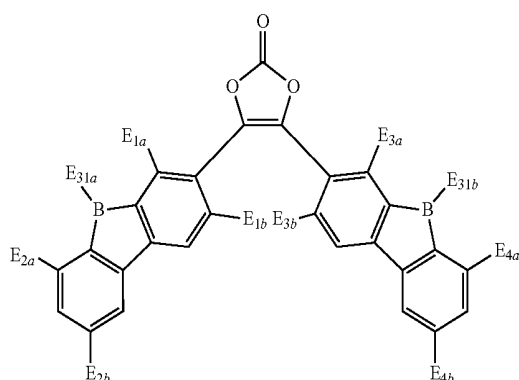
wherein Q₁₁ to Q₁₇, Q₂₁ to Q₂₇, and Q₃₁ to Q₃₇ are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazine group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

15. The dibenzoborole-based compound of claim 1, represented by one selected from Formulae 1-1(1)1 to 1-7(1)1:

Formula 1-1(1)1

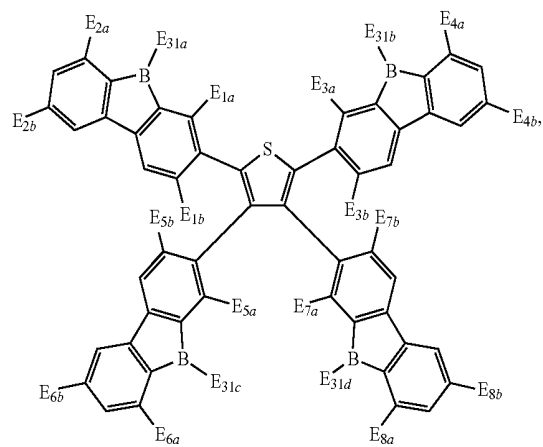


Formula 1-2(1)1

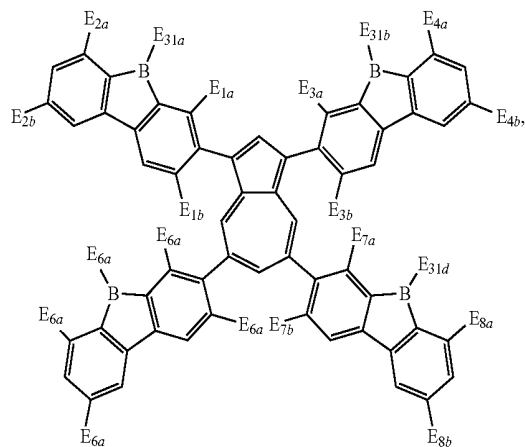


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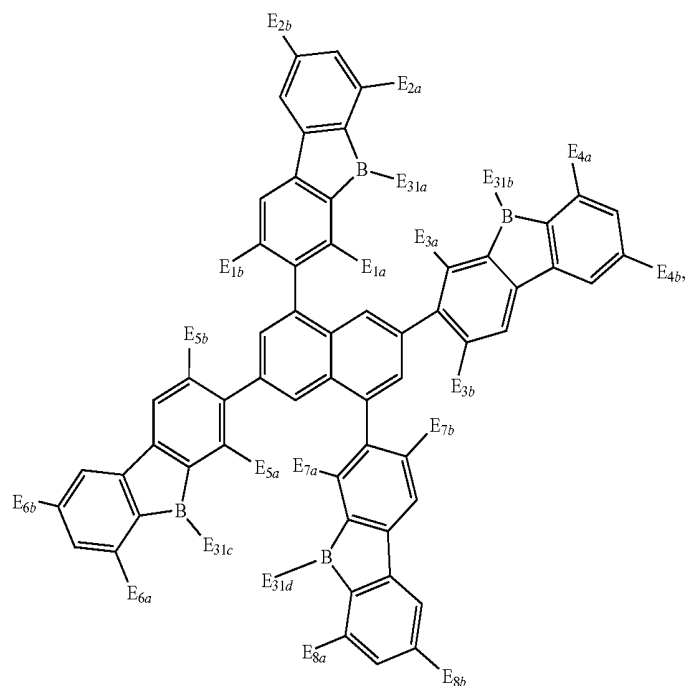
Formula 1-3(1)1



Formula 1-4(1)1

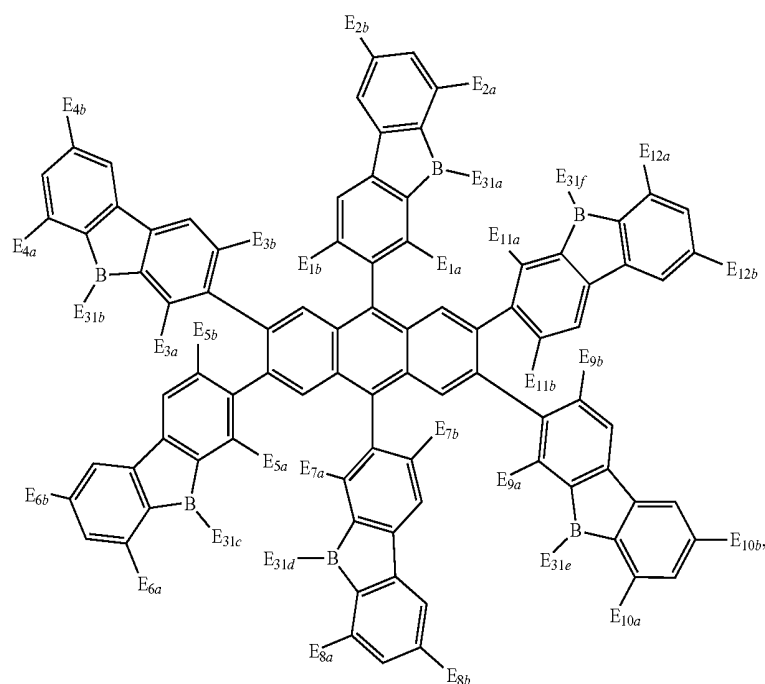


Formula 1-5(1)1

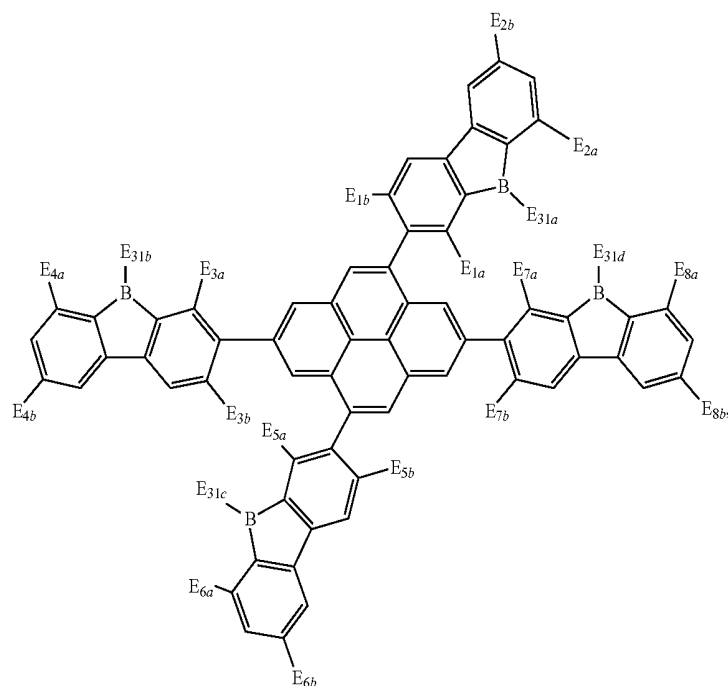


-continued

Formula 1-6(1)1



Formula 1-7(1)1



wherein, in Formulae 1-1(1)1 to 1-7(1)1,

E_{1a} , E_{1b} , E_{3a} , E_{3b} , E_{5a} , E_{5b} , E_{7a} , E_{7b} , E_{9a} , E_{9b} , E_{11a} , and E_{11b} are the same as E_1 ,

E_{2a} , E_{2b} , E_{4a} , E_{4b} , E_{6a} , E_{6b} , E_{8a} , E_{8b} , E_{10a} , E_{10b} , E_{12a} , and E_{12b} are the same as E_2 , and

E_{31a} to E_{31f} are the same as E_{31} .

16. The dibenzoborole-based compound of claim 1, wherein the dibenzoborole-based compound has an electron affinity of about 4.5 eV to about 5.0 eV.

17. An organic light-emitting device comprising a first electrode; a second electrode; and an organic layer between

the first electrode and the second electrode and comprising an emission layer, wherein the organic layer comprises the dibenzoborole-based compound of claim 1.

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

the first electrode is an anode,

the second electrode is a cathode,

the organic layer comprises i) a hole transport region between the first electrode and the emission layer that comprises at least one selected from a hole injection layer, a hole transport layer, a buffer layer, and an

electron blocking layer and ii) an electron transport region between the emission layer and the second electrode that comprises at least one selected from a hole blocking layer, an electron transport layer, and an electron injection layer, and the hole transport region comprises the dibenzoborole-based compound.

19. The organic light-emitting device of claim **18**, wherein the hole transport region comprises the hole transport layer, and the hole transport layer comprises the dibenzoborole-based compound.

20. The organic light-emitting device of claim **19**, wherein the hole transport layer further comprises a matrix material, and an amount of the dibenzoborole-based compound in the hole transport layer is about 0.5 part by weight to about 2 parts by weight, based on 100 parts by weight of the matrix material.

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摘要(译)

基于二苯并硼杂的化合物和包含其的有机发光装置。基于二苯并硼杂的化合物由式A 1 - (A 2) n1 表示，其中A 1 可以选自特定的芳族和非芳族碳环和杂环，n1可以是选自1至10的整数，并且每个A 2 部分可以独立地选自式2表示的基团：基于二苯并硼杂的化合物可以包含在空穴传输区域或空穴传输层中。当二苯并硼杂环化合物具有强电子受体特性时，阳极和有机层之间的空穴注入势垒可以减小，因此，包含二苯并硼杂环化合物的有机发光器件可以具有高效率 and 长寿命。。

