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Lee et al.(10) **Pub. No.: US 2017/0155056 A1**(43) **Pub. Date: Jun. 1, 2017**(54) **COMPOUND AND ORGANIC
LIGHT-EMITTING DEVICE****H01L 51/0058** (2013.01); **C07D 403/10**
(2013.01); **C07F 9/5728** (2013.01); **H01L**
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(57)

ABSTRACT

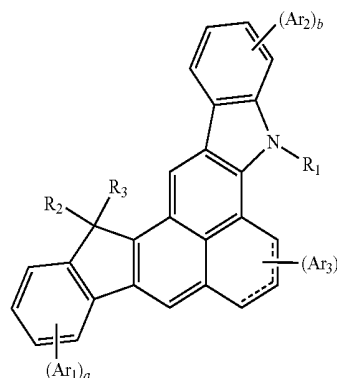
An organic light-emitting device including: a first electrode;
a second electrode facing the first electrode; and an organic
layer between the first electrode and the second electrode,
the organic layer including an emission layer, wherein the
organic layer includes a compound represented by Formula
1:

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C07D 401/04 (2006.01)
C07D 403/10 (2006.01)
H01L 27/32 (2006.01)
C07D 403/04 (2006.01)(52) **U.S. Cl.**CPC **H01L 51/0072** (2013.01); **H01L 27/3248**
(2013.01); **C07D 403/04** (2013.01); **H01L**
51/0067 (2013.01); **C07D 401/04** (2013.01);

Formula 1



When the compound of Formula 1 is used as an electron
transport material, an organic light-emitting device includ-
ing the compound may have high efficiency, low driving
voltage, high brightness, and long lifespan.

40

220

190

150

110

210

FIG. 1

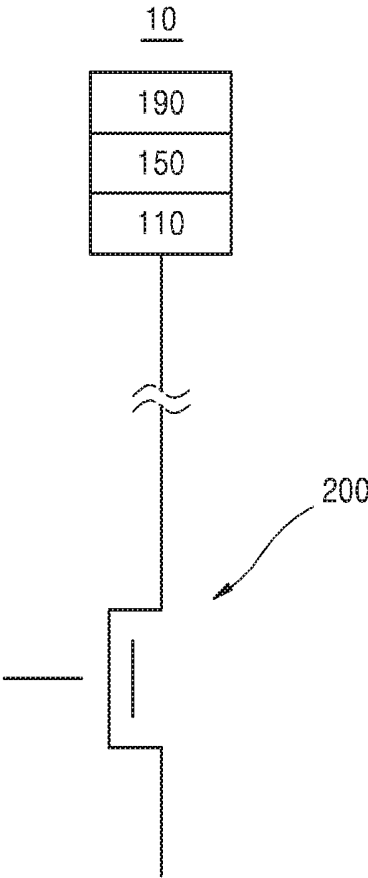


FIG. 2

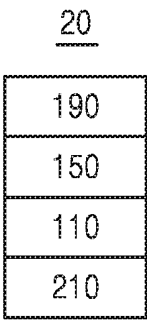


FIG. 3

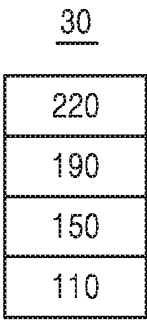
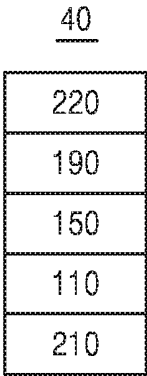


FIG. 4



COMPOUND AND ORGANIC LIGHT-EMITTING DEVICE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to and the benefit of Korean Patent Application No. 10-2015-0166413, filed on Nov. 26, 2015, in the Korean Intellectual Property Office, the entire content of which is incorporated herein by reference.

BACKGROUND

1. Field

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

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

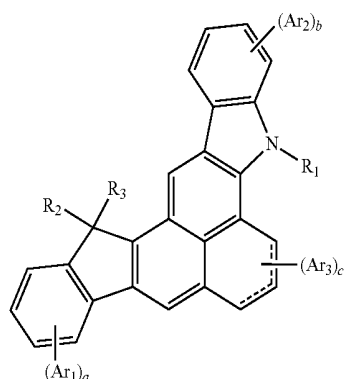
[0004] An organic light-emitting device may include a first electrode on a substrate, and a hole transport region, an emission layer, an electron transport region, and a second electrode sequentially positioned on the first electrode. Holes provided from the first electrode may move toward the emission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

SUMMARY

[0005] One or more aspects of example embodiments of the present disclosure are directed toward a compound suitable for use as an electron injection and/or transport material, due to its excellent electron injection and/or transport capability and material stability, and an organic light-emitting device including the compound that accordingly has high efficiency, low driving voltage, high brightness, and long lifespan.

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

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



Formula 1

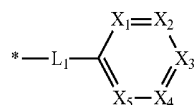
[0008] In Formula 1,

[0009] R₂ and R₃ may each independently be selected from hydrogen, deuterium, a halogen atom, a nitro group, a cyano 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 C₂-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₂-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group,

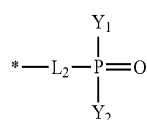
[0010] Ar₁ to Ar₃ may each independently be selected from hydrogen, deuterium, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, a substituted or unsubstituted C₅-C₆₀ carbocyclic group, and a substituted or unsubstituted C₁-C₆₀ heterocyclic group,

[0011] a to c may each independently be an integer selected from 0 to 2, and

[0012] R₁ may be one selected from Formulae 1-1 and 1-2:



Formula 1-1



Formula 1-2

[0013] In Formulae 1-1 and 1-2,

[0014] X₁ to X₅ may each independently be selected from nitrogen (N) and CR₁₁,

[0015] at least one selected from X₁ to X₅ may be N;

[0016] R₁₁, Y₁, and Y₂ may each independently be selected from a substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group,

[0017] L₁ and L₂ may each independently be selected from a substituted or unsubstituted C₆-C₆₀ arylene group, a substituted or unsubstituted C₁-C₆₀ heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0018] * may indicate a binding site, and

[0019] at least one substituent selected from the substituted C₁-C₆₀ alkyl group, the substituted C₂-C₆₀ alkenyl

group, the substituted C_2 - C_{60} alkynyl group, the substituted C_1 - C_{60} alkoxy group, the substituted C_3 - C_{10} cycloalkyl group, the substituted C_2 - C_{10} heterocycloalkyl group, the substituted C_3 - C_{10} cycloalkenyl group, the substituted C_2 - C_{10} heterocycloalkenyl group, the substituted C_6 - C_{60} aryl group, the substituted C_6 - C_{60} aryloxy group, the substituted C_6 - C_{60} arylthio group, the substituted C_1 - C_{60} heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, the substituted monovalent non-aromatic condensed heteropolycyclic group, the substituted C_5 - C_{60} carbocyclic group, the substituted C_1 - C_{60} heterocyclic group, the substituted C_6 - C_{60} arylene group, the substituted C_1 - C_{60} heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, and the substituted divalent non-aromatic condensed heteropolycyclic group may be selected from the group consisting of:

[0020] 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;

[0021] 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_2 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_2 - 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});

[0022] a C_3 - C_{10} cycloalkyl group, a C_2 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_2 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_1 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group; and

[0023] a C_3 - C_{10} cycloalkyl group, a C_2 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_2 - 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_2 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_2 - 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}),

[0024] wherein Q_{11} to Q_{17} and Q_{21} to Q_{27} 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 C_3 - C_{10} cycloalkyl group, a C_2 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_2 - 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.

[0025] One or more aspects of embodiments of the present disclosure provide an organic light-emitting device including: a first electrode; a second electrode facing the first electrode; and an organic layer between the first electrode and the second electrode, the organic layer including an emission layer, wherein the organic layer includes the compound.

[0026] One or more aspects of embodiments of the present disclosure provide a display apparatus including the organic light-emitting device, wherein the first electrode of the organic light-emitting device is electrically connected to a source electrode or drain electrode of a thin film transistor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] These and/or other aspects will become apparent and more readily appreciated from the following description of the example embodiments, taken in conjunction with the accompanying drawings in which:

[0028] FIG. 1 is a schematic diagram of a structure of an organic light-emitting device according to an embodiment of the present disclosure;

[0029] FIG. 2 is a schematic diagram of a structure of an organic light-emitting device according to another embodiment of the present disclosure;

[0030] FIG. 3 is a schematic diagram of a structure of an organic light-emitting device according to another embodiment of the present disclosure; and

[0031] FIG. 4 is a schematic diagram of a structure of an organic light-emitting device according to another embodiment of the present disclosure.

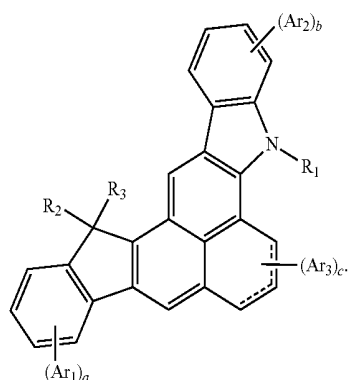
DETAILED DESCRIPTION

[0032] Reference will now be made in more detail to embodiments, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout and duplicative descriptions thereof may not be provided. In this regard, the present embodiments may have different forms and should not be construed as being limited to the descriptions set forth herein. Accordingly, the embodiments are merely described below, by referring to the 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”, and “selected from”, when preceding a list of

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

[0033] In the drawings, the thicknesses 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.

[0034] One or more aspects of embodiments of the present disclosure provide a compound represented by Formula 1:



Formula 1

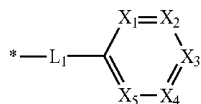
[0035] In Formula 1,

[0036] R_2 and R_3 may each independently be selected from hydrogen, deuterium, a halogen atom, a nitro group, a cyano 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_2 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_2 - 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,

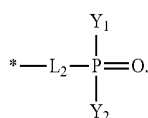
[0037] Ar_1 to Ar_3 may each independently be selected from hydrogen, deuterium, a substituted or unsubstituted C_6 - C_{60} aryl group, a substituted or unsubstituted C_6 - C_{60} aryloxy group, a substituted or unsubstituted C_6 - C_{60} arylthio group, a substituted or unsubstituted C_1 - C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, a substituted or unsubstituted C_5 - C_{60} carbocyclic group, and a substituted or unsubstituted C_1 - C_{60} heterocyclic group,

[0038] a to c may each independently be an integer selected from 0 to 2, and

[0039] R_1 may be one selected from Formulae 1-1 and 1-2:



Formula 1-1



Formula 1-2

[0040] In Formulae 1-1 and 1-2,

[0041] X_1 to X_5 may each independently be selected from nitrogen (N) and CR_{11} ,

[0042] at least one selected from X_1 to X_5 may be N,

[0043] R_{11} , Y_1 , and Y_2 may each independently be selected from a substituted or unsubstituted C_1 - C_{60} alkyl group, a substituted or unsubstituted C_6 - C_{60} aryl group, a substituted or unsubstituted C_1 - C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group,

[0044] L_1 and L_2 may each independently be selected from 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,

[0045] * may indicate a binding site, and

[0046] at least one substituent selected from the substituted C_1 - C_{60} alkyl group, the substituted C_2 - C_{60} alkenyl group, the substituted C_2 - C_{60} alkynyl group, the substituted C_1 - C_{60} alkoxy group, the substituted C_3 - C_{10} cycloalkyl group, the substituted C_2 - C_{10} heterocycloalkyl group, the substituted C_3 - C_{10} cycloalkenyl group, the substituted C_2 - C_{10} heterocycloalkenyl group, the substituted C_6 - C_{60} aryl group, the substituted C_6 - C_{60} aryloxy group, the substituted C_6 - C_{60} arylthio group, the substituted C_1 - C_{60} heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, the substituted monovalent non-aromatic condensed heteropolycyclic group, the substituted C_5 - C_{60} carbocyclic group, the substituted C_1 - C_{60} heterocyclic group, the substituted C_6 - C_{60} arylene group, the substituted C_1 - C_{60} heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, and the substituted divalent non-aromatic condensed heteropolycyclic group may be selected from the group consisting of:

[0047] 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;

[0048] 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

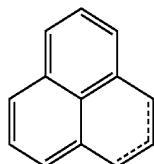
C₂-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₂-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q₁₁)(Q₁₂), —Si(Q₁₃)(Q₁₄)(Q₁₅), and —B(Q₁₆)(Q₁₇);

[0049] a C₃-C₁₀ cycloalkyl group, a C₂-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₂-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; and

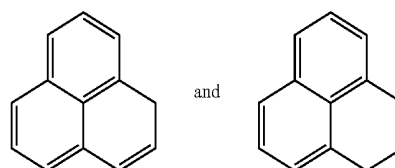
[0050] a C₃-C₁₀ cycloalkyl group, a C₂-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₂-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic 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 C₂-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₂-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),

[0051] wherein Q₁₁ to Q₁₇ and Q₂₁ to Q₂₇ 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 C₂-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₂-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.

[0052] As used herein, in Formula 1, the dashed line in the phenylene moiety indicates that a double bond may be included on either side of the dashed portion. For example, a moiety shown as

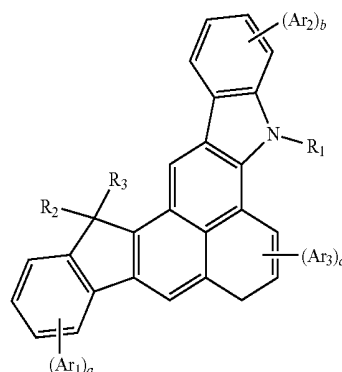


may include one selected from



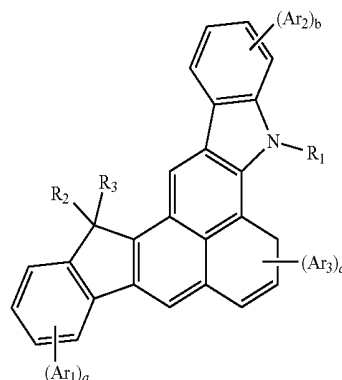
[0053] In one or more embodiments, the compound represented by Formula 1 may be represented by Formula 2:

Formula 2



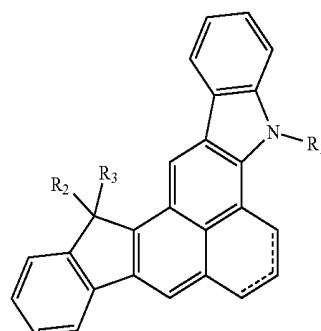
[0054] In one or more embodiments, the compound represented by Formula 1 may be represented by Formula 3:

Formula 3



[0055] In one or more embodiments, the compound represented by Formula 1 may be represented by Formula 4:

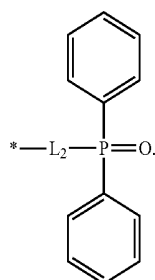
Formula 4



[0056] In Formulae 2 to 4, R_1 to R_3 , Ar_1 to Ar_3 , and a to c may each independently be the same as described herein in connection with Formula 1.

[0057] In one or more embodiments, in Formula 1-1, one selected from X_1 and X_3 may be N, X_1 and X_5 may each independently be N, X_1 and X_3 may each independently be N, or X_1 , X_3 , and X_5 may each independently be N.

[0058] In one or more embodiments, the group represented by Formula 1-2 may be represented by Formula 1-3:

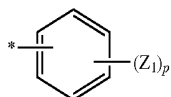


Formula 1-3

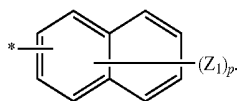
[0059] In Formula 1-3, L_2 may be the same as described herein in connection with Formula 1-2.

[0060] In one or more embodiments, R_2 and R_3 may each independently be a substituted or unsubstituted C_1 - C_{20} alkyl group. For example, R_2 and R_3 may each independently be a methyl group.

[0061] In one or more embodiments, R_{11} may be represented by one selected from Formulae 2a to 2b:



2a



2b

[0062] In Formulae 2a to 2b,

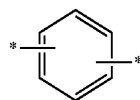
[0063] Z_1 may be selected from hydrogen, deuterium, a halogen group (e.g., atom), a cyano group, a nitro group, a hydroxyl group, a carboxyl group, a substituted or unsubstituted C_1 - C_{20} alkyl group, a substituted or unsubstituted C_6 - C_{20} aryl group, a substituted or unsubstituted C_1 - C_{20} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group,

[0064] p may be an integer selected from 1 to 7,

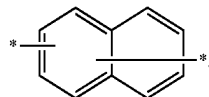
[0065] when p is 2 or greater, a plurality of Z_1 (s) may be identical to or different from each other, and

[0066] $*$ may indicate a binding site.

[0067] In one or more embodiments, L_1 and L_2 may each independently be represented by one selected from Formulae 3a to 3b:



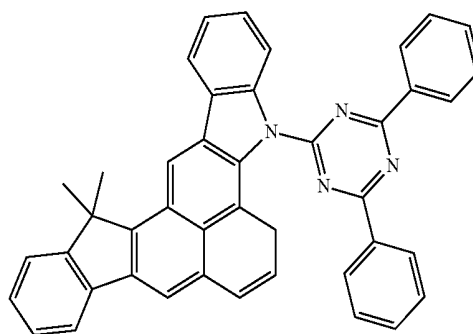
3a



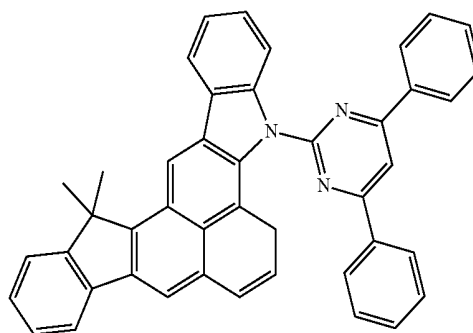
3b

[0068] In Formulae 3a to 3b, $*$ may indicate a binding site.

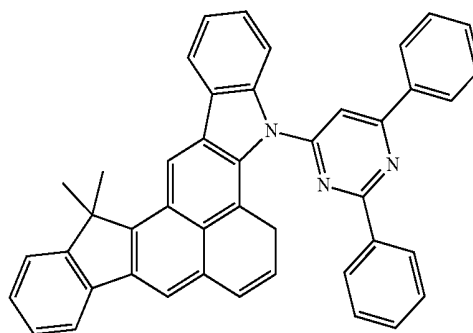
[0069] In one or more embodiments, the compound represented by Formula 1 may be one selected from Compounds ET1 to ET42, but embodiments of the present disclosure are not limited thereto:



ET-1



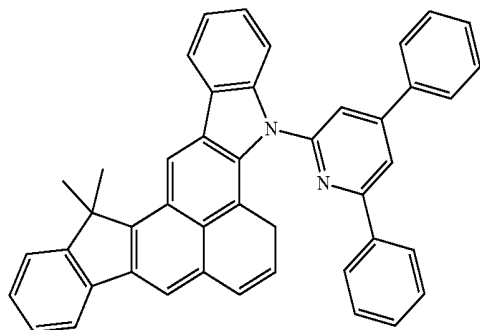
ET-2



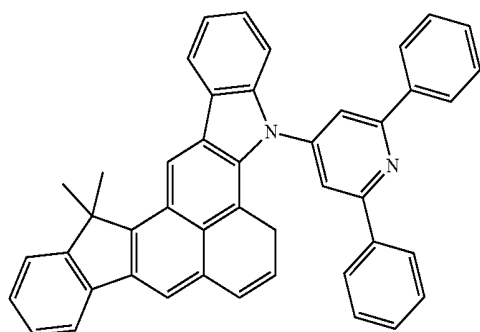
ET-3

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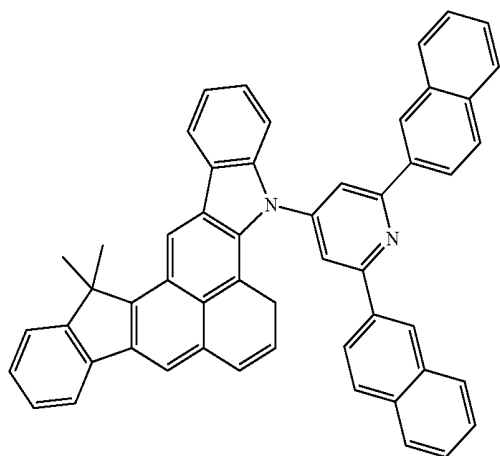
ET-4



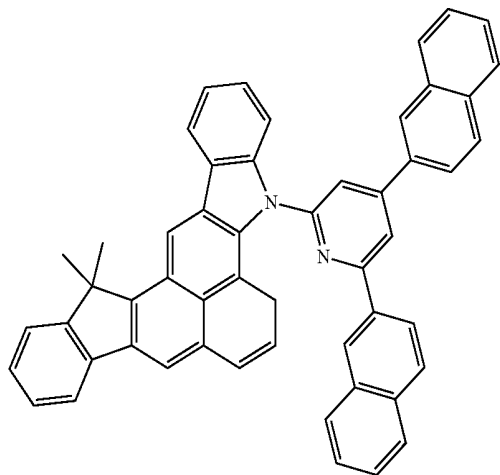
ET-5



ET-6

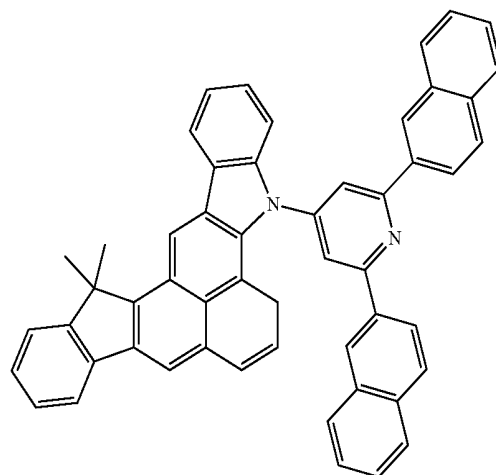


ET-7

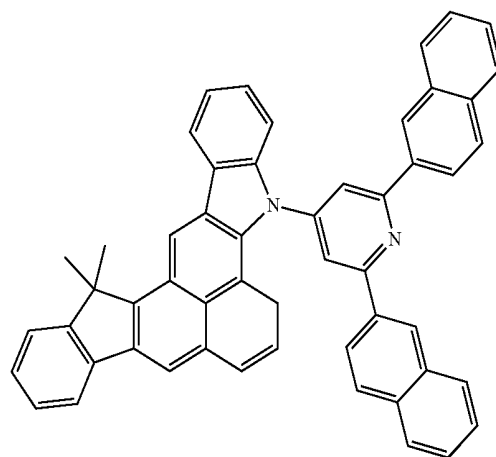


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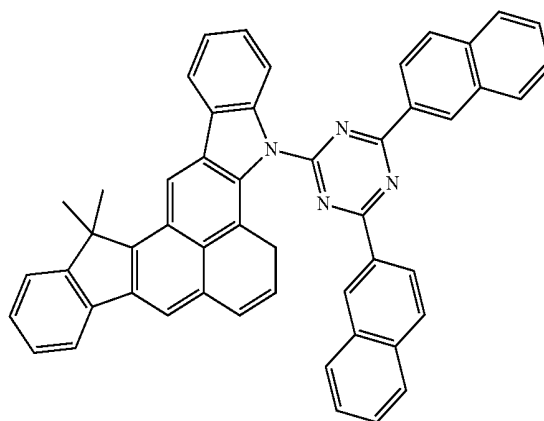
ET-8



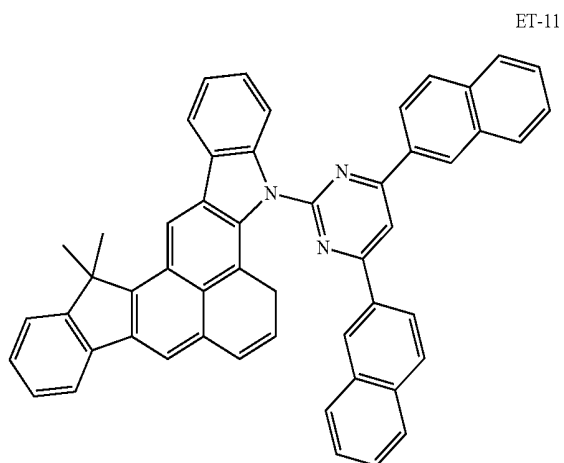
ET-9



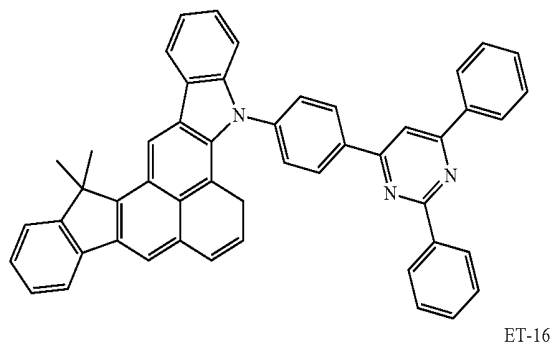
ET-10



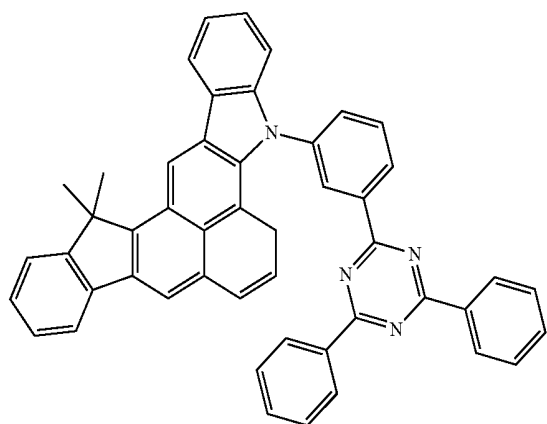
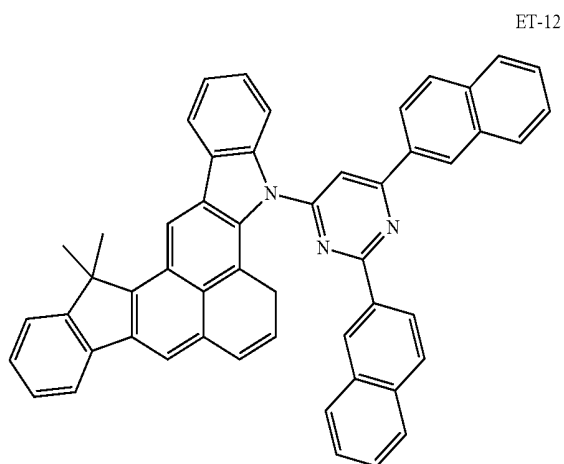
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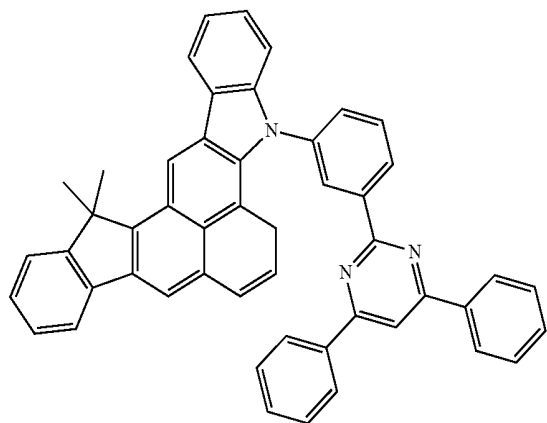
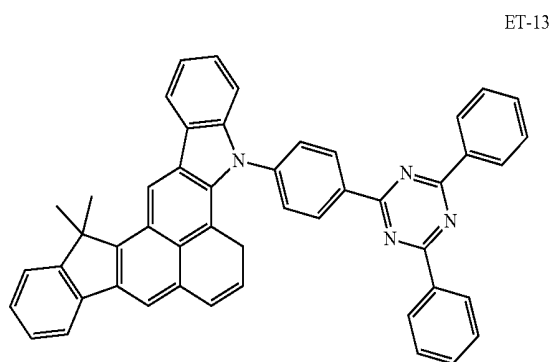
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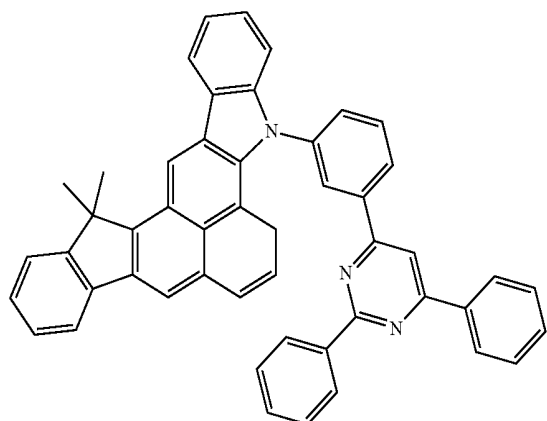
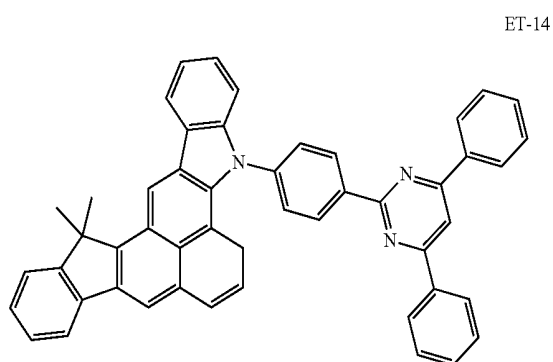
ET-16



ET-17

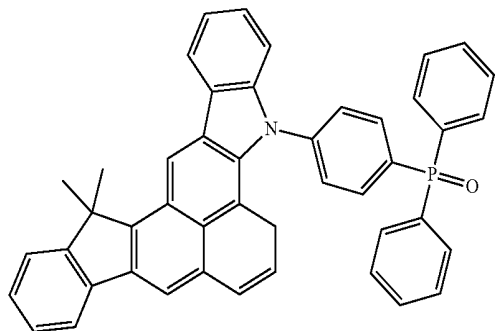


ET-18

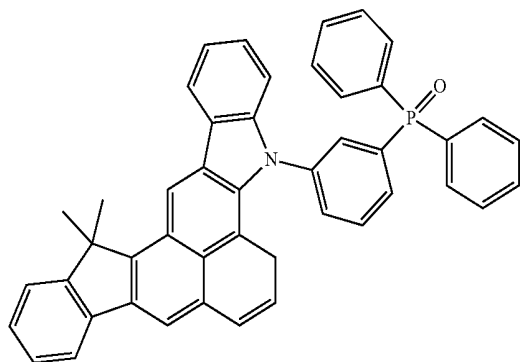


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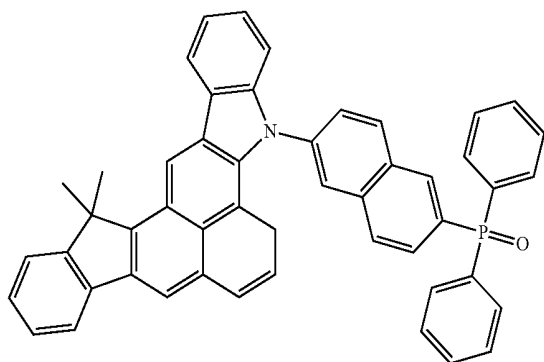
ET-19



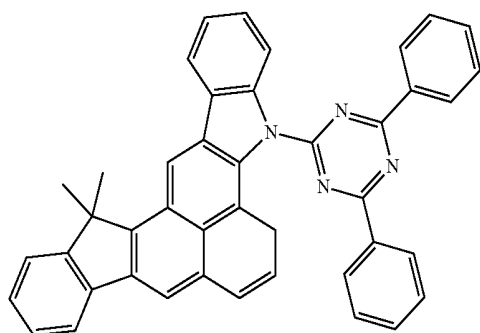
ET-20



ET-21

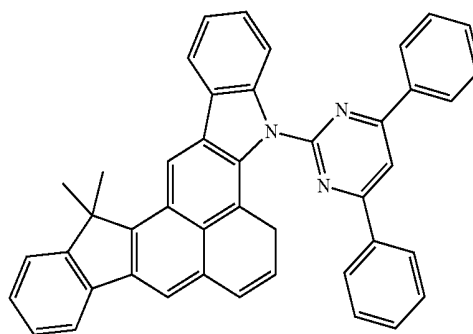


ET-22

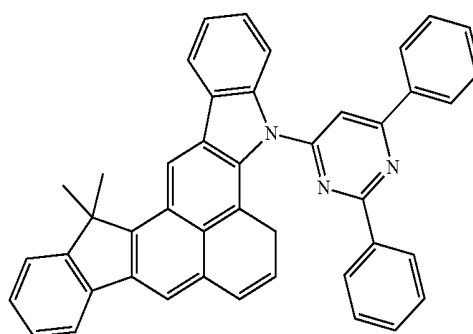


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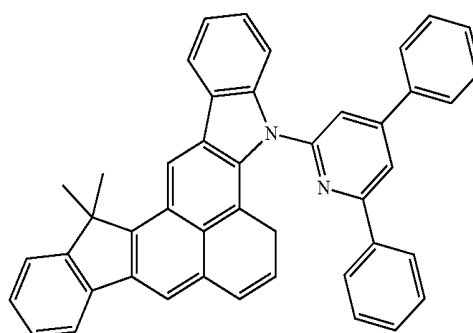
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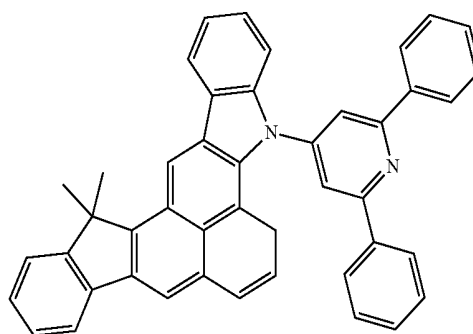
ET-24



ET-25



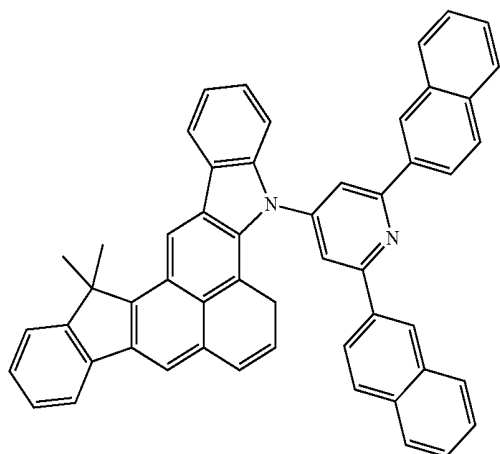
ET-26



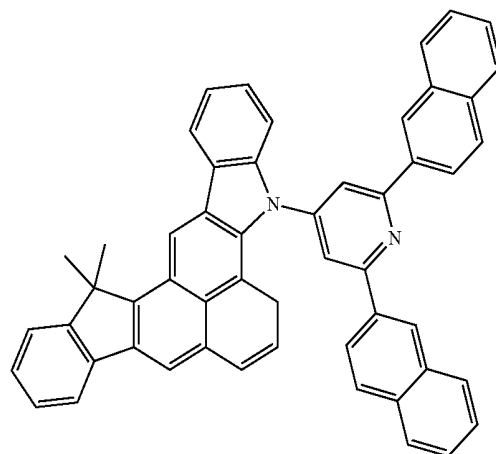
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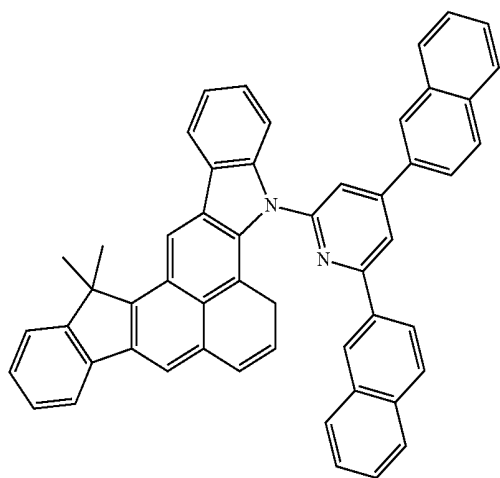
ET-27



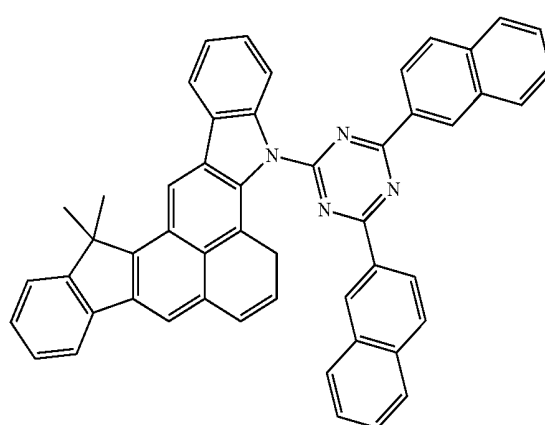
ET-30



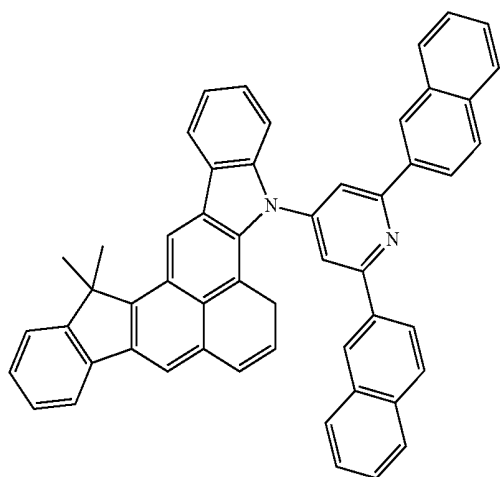
ET-28



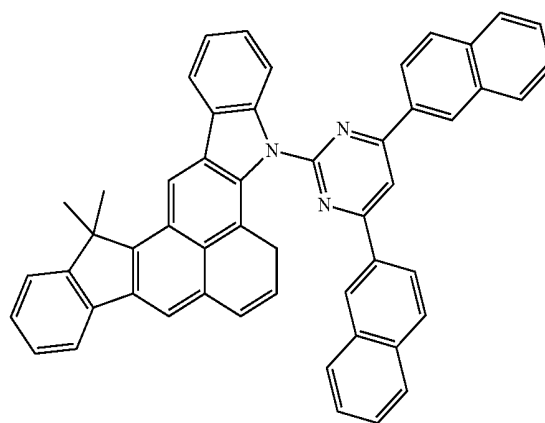
ET-31



ET-29

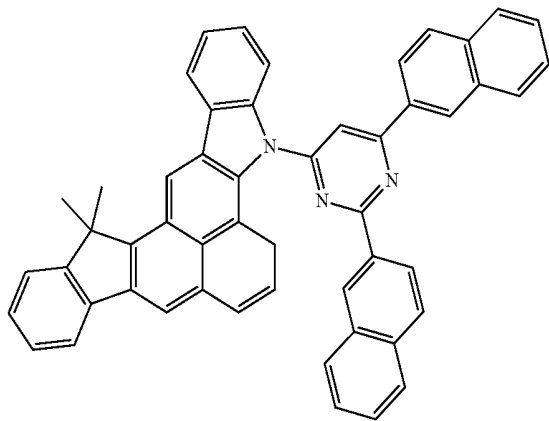


ET-32



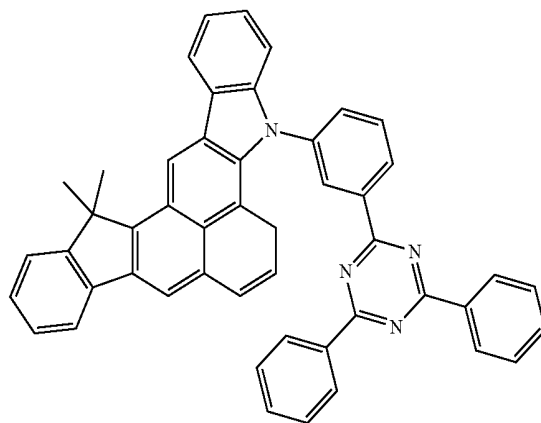
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ET-33

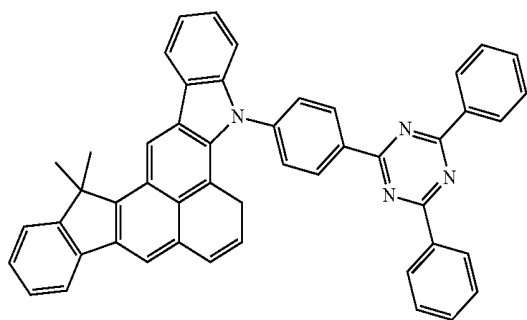


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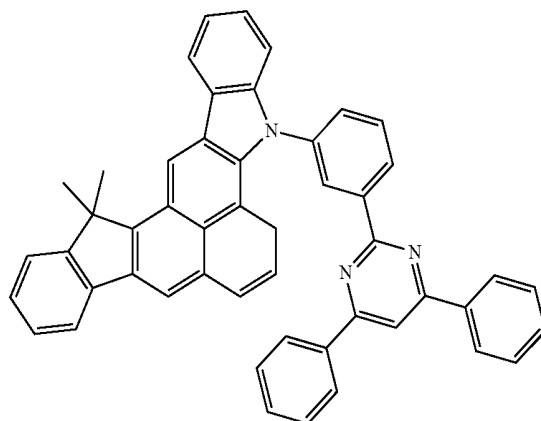
ET-37



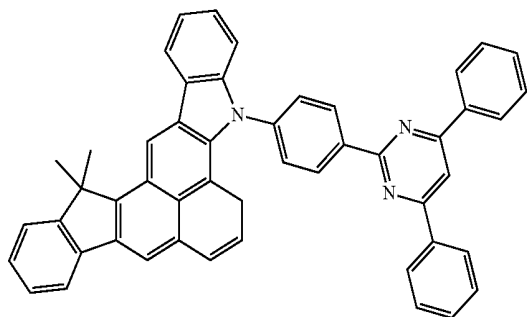
ET-34



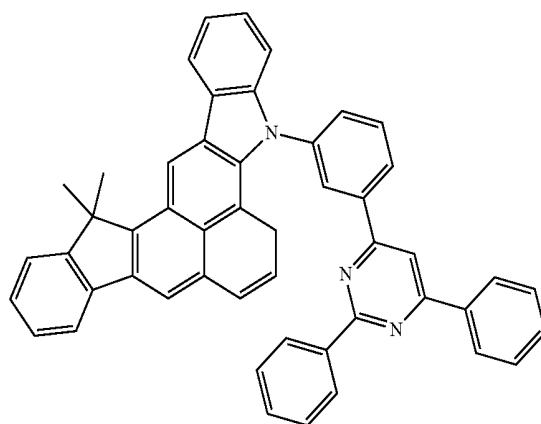
ET-38



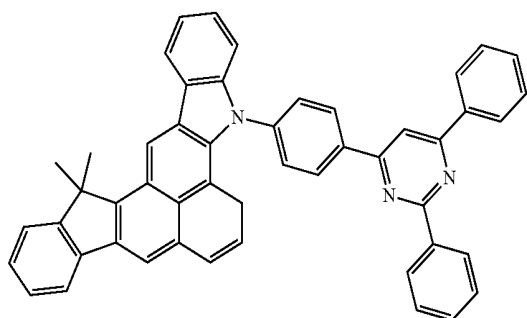
ET-35



ET-39

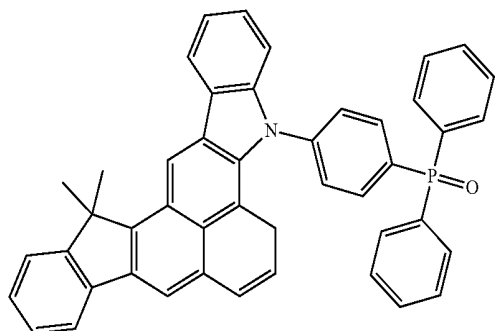


ET-36

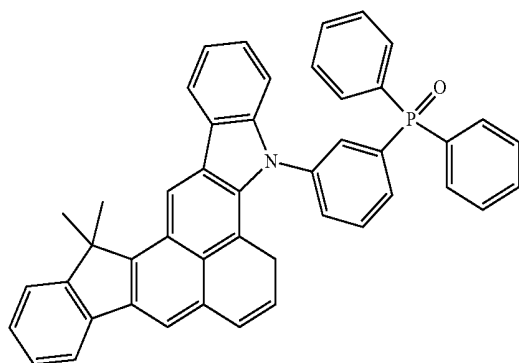


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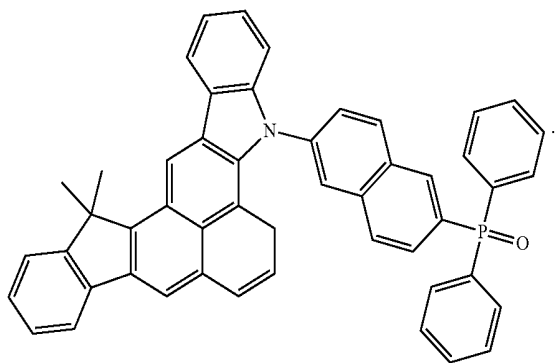
ET-40



ET-41



ET-42



Description of FIG. 1

[0070] FIG. 1 is a schematic cross-sectional view of a structure of an organic light-emitting device 10 according to an embodiment of the present disclosure. The organic light-emitting device 10 includes a first electrode 110, an organic layer 150, and a second electrode 190.

[0071] Hereinafter, the structure of the organic light-emitting device 10 according to an embodiment of the present disclosure and a method of manufacturing the organic light-emitting device 10 will be described in connection with FIG. 1.

First Electrode 110

[0072] In FIG. 1, a substrate may be under the first electrode 110 and/or above the second electrode 190. The

substrate may be a glass substrate or a plastic substrate, each having excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and/or water-resistance.

[0073] The first electrode 110 may be formed by depositing or sputtering a material for forming the first electrode 110 on the substrate. When the first electrode 110 is an anode, the material for forming the first electrode may be selected from materials with a high work function to facilitate hole injection.

[0074] The first electrode 110 may be a reflective electrode, a semi-transmissive electrode, or a transmissive electrode. The first electrode 110 may be a reflective electrode, a semi-transmissive electrode, or a transmissive electrode. When the first electrode 110 is a transmissive electrode, the material for forming a first electrode 110 may be selected from indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO₂), zinc oxide (ZnO), and combinations thereof, but embodiments of the present disclosure are not limited thereto. In one or more embodiments, when the first electrode 110 is a semi-transmissive electrode or a reflective electrode, the material for forming the first electrode 110 may be selected from magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), magnesium-silver (Mg—Ag), and combinations thereof, but embodiments of the present disclosure are not limited thereto.

[0075] The first electrode 110 may have a single-layer structure, or a multi-layer structure including two or more layers. For example, the first electrode 110 may have a three-layered structure of ITO/Ag/ITO, but embodiments of the structure of the first electrode 110 are not limited thereto.

Organic Layer 150

[0076] The organic layer 150 is on the first electrode 110. The organic layer 150 may include an emission layer.

[0077] The organic layer 150 may further include a hole transport region between the first electrode 110 and the emission layer, and an electron transport region between the emission layer and the second electrode 190.

Hole Transport Region in Organic Layer 150

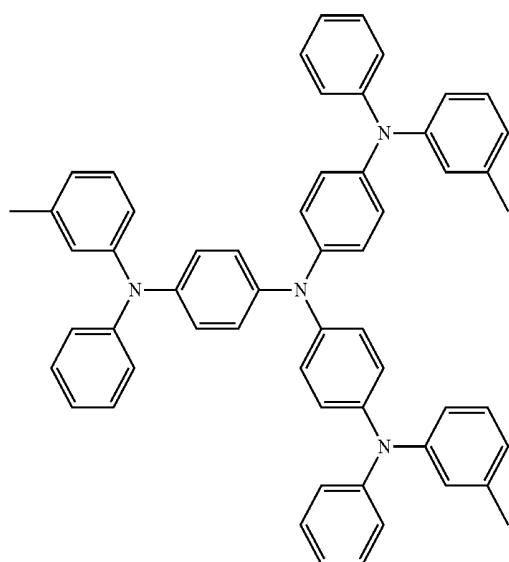
[0078] The hole transport region may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

[0079] The hole transport region may include at least one layer selected from a hole injection layer (HIL), a hole transport layer (HTL), an emission auxiliary layer, and an electron blocking layer (EBL).

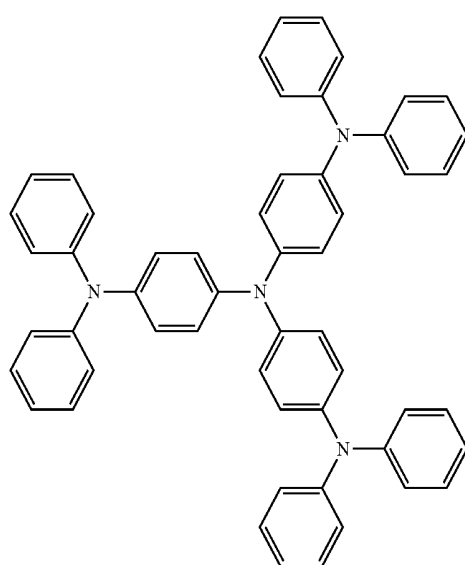
[0080] For example, the hole transport region may have a single-layered structure including a single layer including a plurality of different materials, a multi-layered structure having a structure of hole injection layer/hole transport layer, a structure of hole injection layer/hole transport layer/emission auxiliary layer, a structure of hole injection layer/emission auxiliary layer, a structure of hole transport layer/emission auxiliary layer, or a structure of hole injection

layer/hole transport layer/electron blocking layer, wherein layers of each structure are sequentially stacked on the first electrode **110** in each stated order, but embodiments of the structure of the hole transport region are not limited thereto.

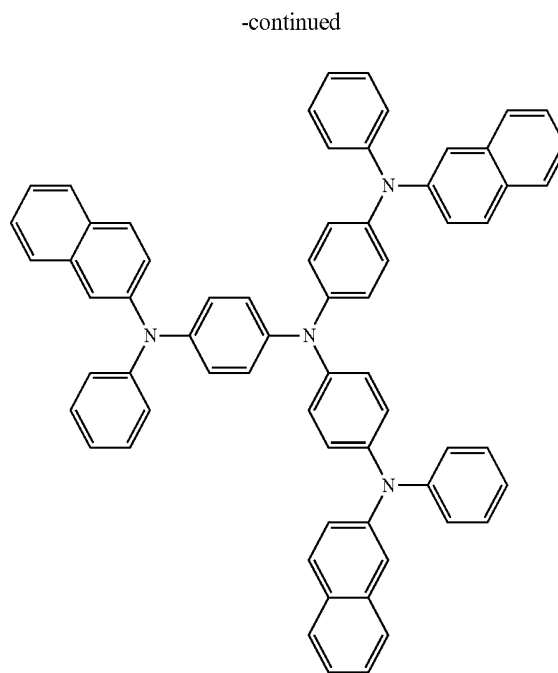
[0081] The hole transport region may include at least one selected from m-MTDATA, TDATA, 2-TNATA, NPB (also referred to as NPD), β -NPB, TPD, Spiro-TPD, Spiro-NPB, methylated NPB, TAPC, HMTPD, 4,4',4''-tris(N-carbazolyl) triphenylamine (TCTA), polyaniline/dodecylbenzenesulfonic acid (PANI/DBSA), poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate) (PEDOT/PSS), polyaniline/camphor sulfonic acid (PANI/CSA), polyaniline/poly(4-styrenesulfonate) (PANI/PSS), a compound represented by Formula 201, and a compound represented by Formula 202:



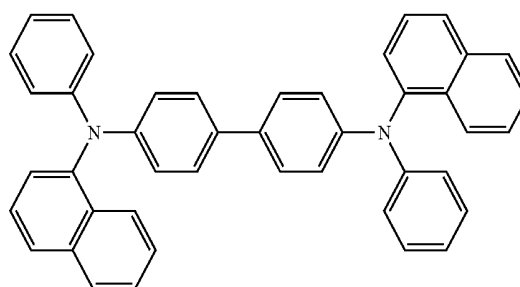
m-MTDATA



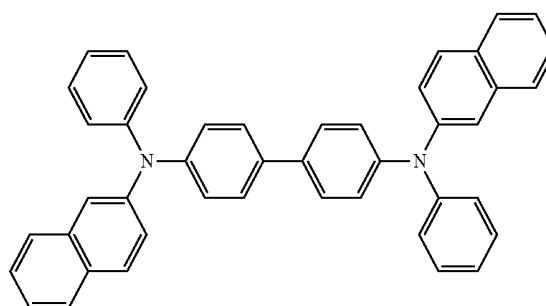
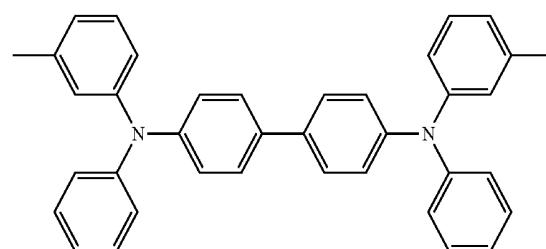
TDATA



2-TNATA

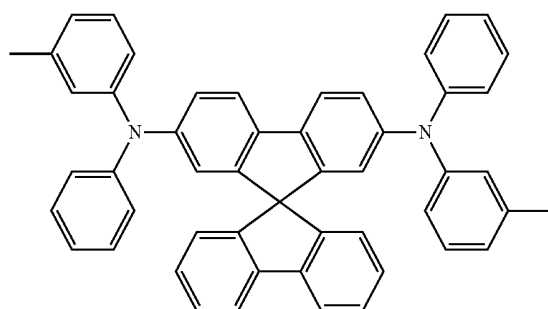


NPB

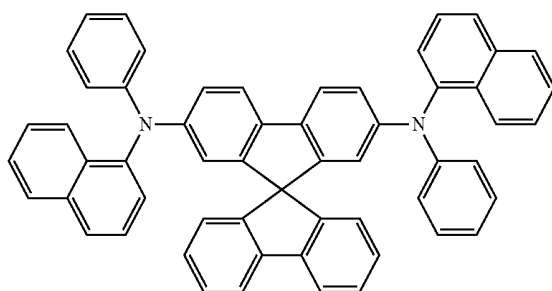
 β -NPB

TPD

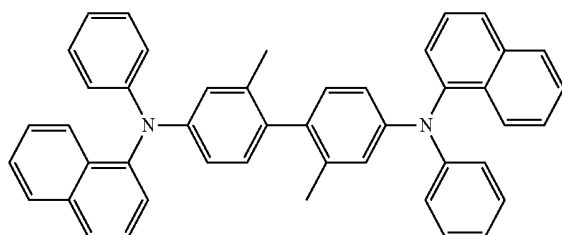
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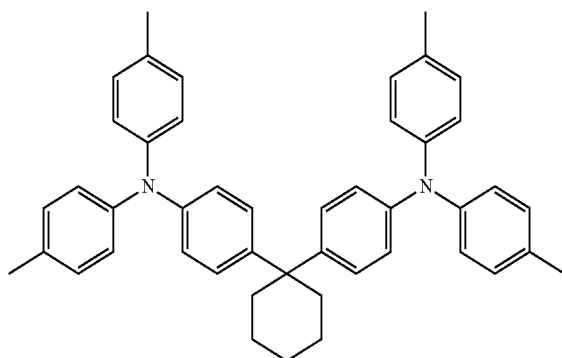
Spiro-TPD



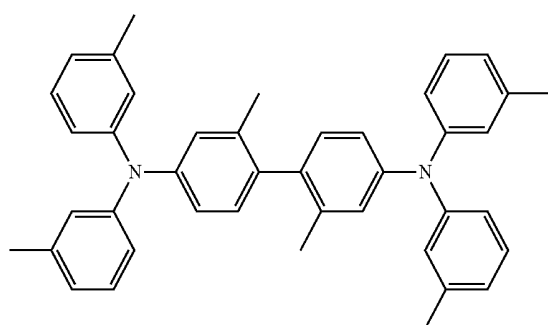
Spiro-NPB



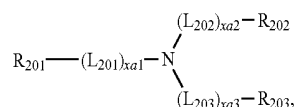
methyated NPB



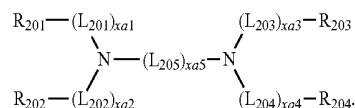
TAPC



HMTPD



Formula 201



Formula 202

[0082] In Formulae 201 and 202,

[0083] L₂₀₁ to L₂₀₄ may each independently be selected from a substituted or unsubstituted C₃-C₁₀ cycloalkylene group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkylene group, a substituted or unsubstituted C₃-C₁₀ cycloalkenylene group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenylene group, a substituted or unsubstituted C₆-C₆₀ arylene group, a substituted or unsubstituted C₁-C₆₀ heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group.

[0084] L₂₀₅ may be selected from *—O—*, *—S—*, *—N(Q₂₀₁)—*, a substituted or unsubstituted C₁-C₂₀ alkylene group, a substituted or unsubstituted C₂-C₂₀ alkenylene group, a substituted or unsubstituted C₃-C₁₀ cycloalkylene group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkylene group, a substituted or unsubstituted C₃-C₁₀ cycloalkenylene group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenylene group, a substituted or unsubstituted C₆-C₆₀ arylene group, a substituted or unsubstituted C₁-C₆₀ heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0085] xa1 to xa4 may each independently be an integer selected from 0 to 3,

[0086] xa5 may be an integer selected from 1 to 10, and

[0087] R₂₀₁ to R₂₀₄ and Q₂₀₁ may each independently be selected from a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group.

[0088] In one or more embodiments, in Formula 202, R₂₀₁ and R₂₀₂ may optionally be connected (e.g., coupled) via a single bond, a dimethyl-methylene group, or a diphenyl-methylene group. In one or more embodiments, in Formula 202, R₂₀₃ and R₂₀₄ may optionally be connected (e.g., coupled) via a single bond, a dimethyl-methylene group, or a diphenyl-methylene group.

[0089] In one or more embodiments, in Formulae 201 and 202,

[0090] L_{201} to L_{205} may each independently be selected from the group consisting of:

[0091] a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an indacenylene group, an acenaphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a rubicenylene group, a coronenylene group, an ovalenylene group, a thiophenylene group, a furanylene group, a carbazolyene group, an indolyene group, an isoindolyene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolyene group, a dibenzocarbazolyene group, a dibenzosilolyene group, and a pyridinylene group; and

[0092] a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an indacenylene group, an acenaphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a rubicenylene group, a coronenylene group, an ovalenylene group, a thiophenylene group, a furanylene group, a carbazolyene group, an indolyene group, an isoindolyene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolyene group, a dibenzocarbazolyene group, a dibenzosilolyene group, and a pyridinylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1 - C_{10} alkyl group, a phenyl group substituted with —F, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, —Si(Q_{31})(Q_{32})(Q_{33}), and —N(Q_{31})(Q_{32}),

[0093] wherein Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0094] In one or more embodiments, xa1 to xa4 may each independently be selected from 0, 1, and 2.

[0095] In one or more embodiments, xa5 may be selected from 1, 2, 3, and 4.

[0096] In one or more embodiments, R_{201} to R_{204} and Q_{201} may each independently be selected from a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group; and

[0097] a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1 - C_{10} alkyl group, a phenyl group substituted with —F, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group.

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

[0098] wherein Q_{31} to Q_{33} may each independently be the same as described above.

[0099] In one or more embodiments, in Formula 201, at least one selected from R_{201} to R_{203} may be selected from the group consisting of:

[0100] a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

[0101] a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1 - C_{10} alkyl group, a phenyl group substituted with $-\text{F}$, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, but embodiments of the present disclosure are not limited thereto.

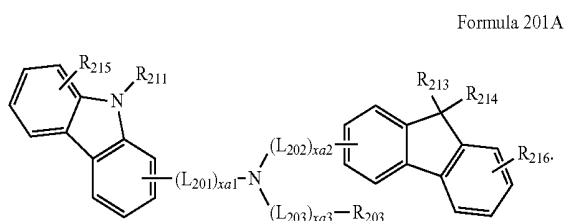
[0102] In one or more embodiments, in Formula 202, i) R_{201} and R_{202} may be connected (e.g., coupled) via a single bond, and/or ii) R_{203} and R_{204} may be connected (e.g., coupled) via a single bond.

[0103] In one or more embodiments, in Formula 202, at least one selected from R_{201} to R_{204} may be selected from the group consisting of:

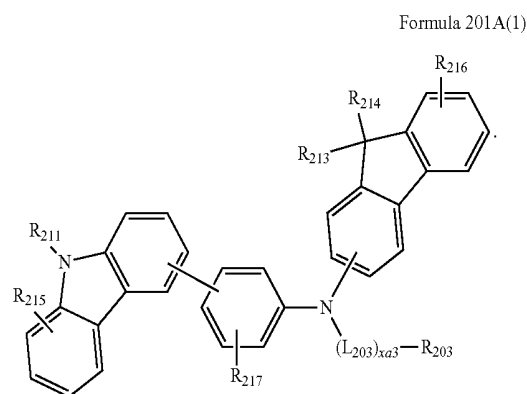
[0104] a carbazolyl group; and

[0105] a carbazolyl group substituted with at least one selected from deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1 - C_{10} alkyl group, a phenyl group substituted with $-\text{F}$, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, but embodiments of the present disclosure are not limited thereto.

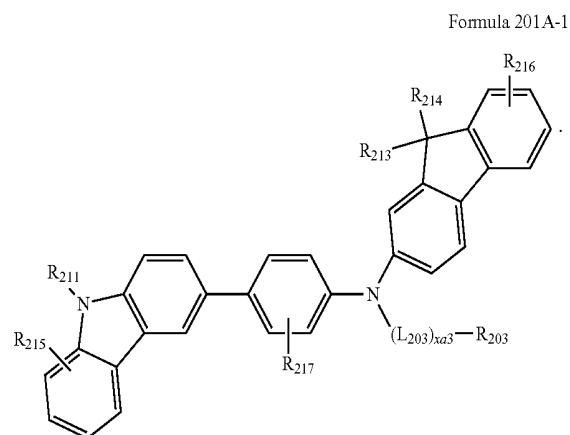
[0106] The compound represented by Formula 201 may be represented by Formula 201A:



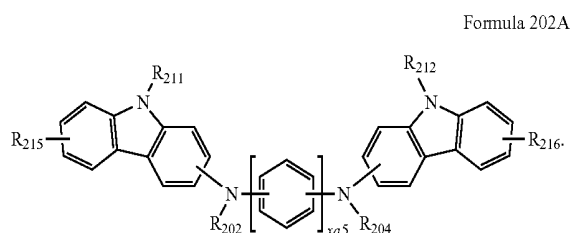
[0107] For example, the compound of Formula 201 may be represented by Formula 201A(1):



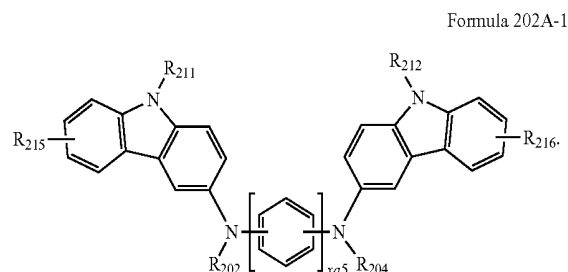
[0108] For example, the compound of Formula 201 may be represented by Formula 201A-1:



[0109] The compound of Formula 202 may be represented by Formula 202A:



[0110] In one or more embodiments, the compound of Formula 202 may be represented by Formula 202A-1:



[0111] In Formulae 201A, 201A(1), 201A-1, 202A, and 202A-1,

[0112] L_{201} to L_{203} , $xa1$ to $xa3$, $xa5$, and R_{202} to R_{204} may each independently be the same as described above,

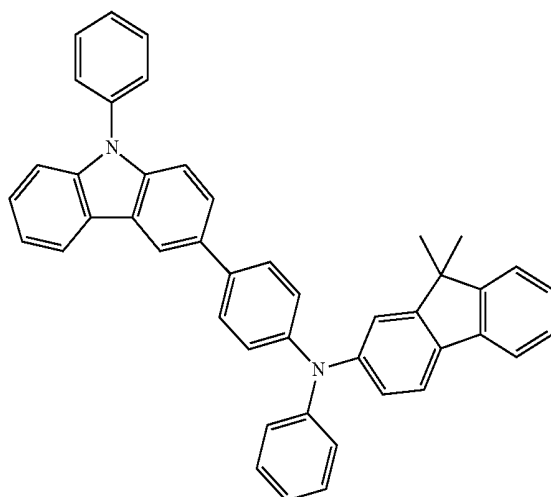
[0113] R_{211} and R_{212} may each independently be the same as described above in connection with R_{203} , and

[0114] R_{213} to R_{217} may each independently be selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a

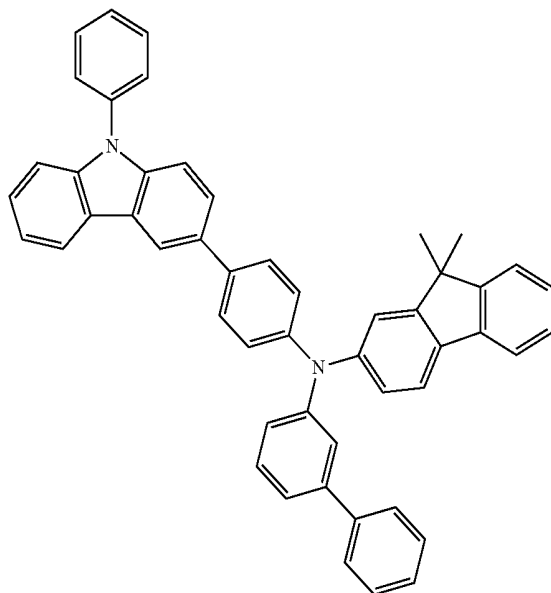
hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1 - C_{10} alkyl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

[0115] The hole transport region may include at least one selected from Compounds HT1 to HT30, but embodiments of the present disclosure are not limited thereto:

HT1

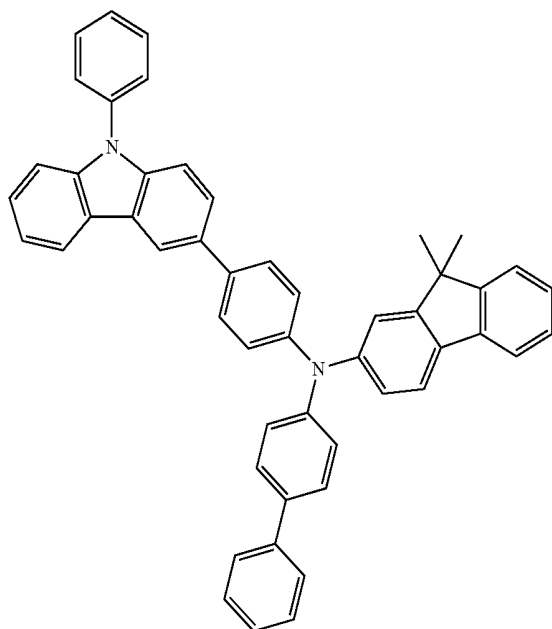


HT2

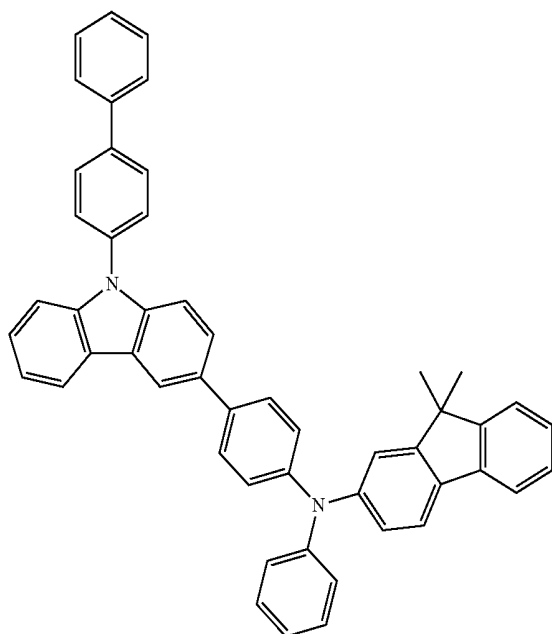


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HT3

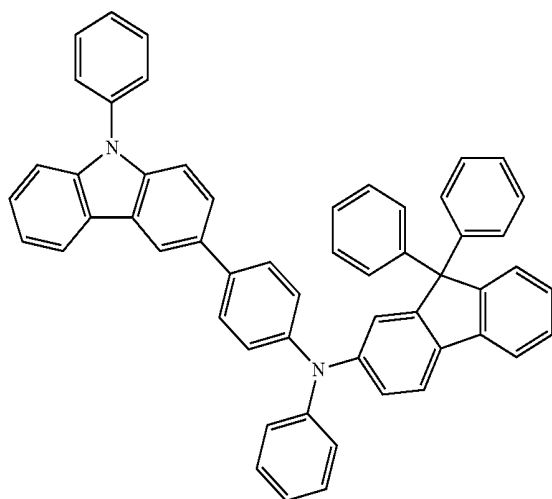


HT4

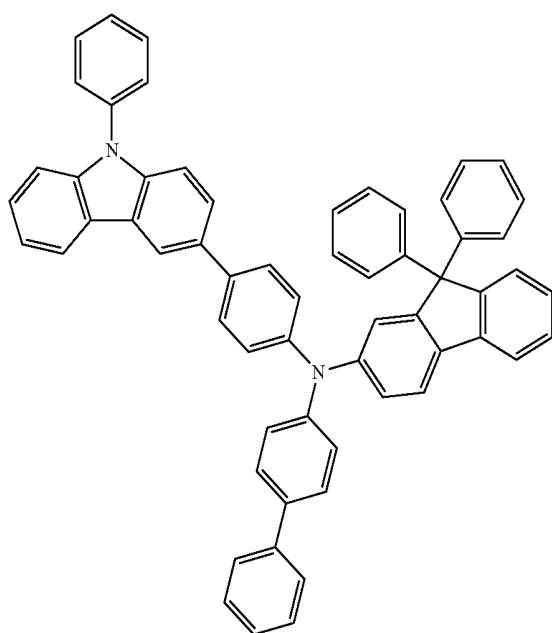


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HT5

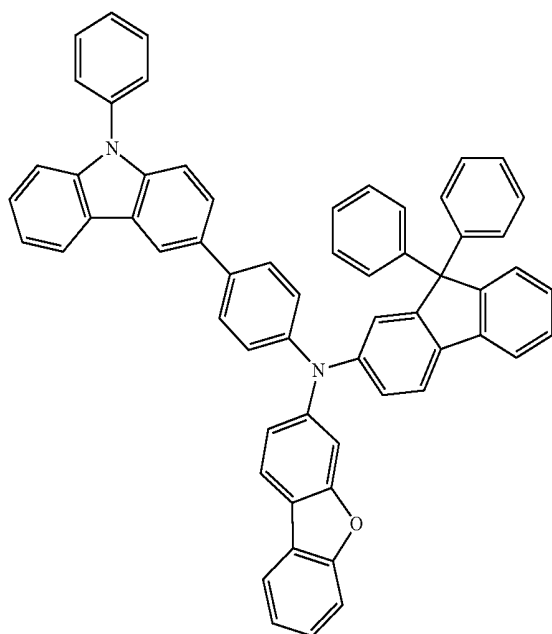


HT6

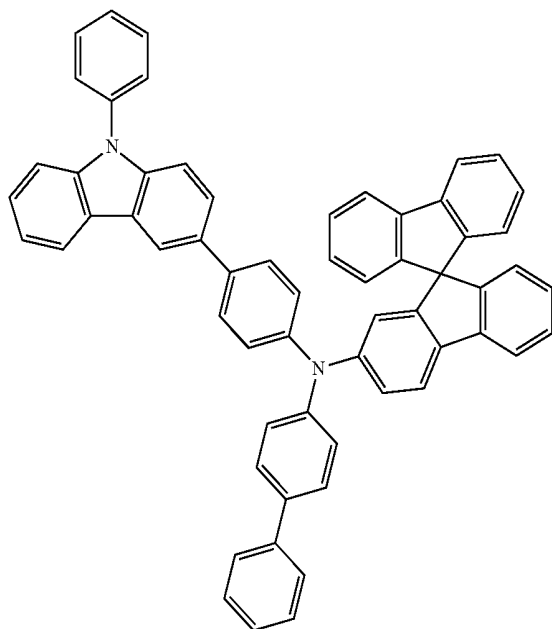


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HT7

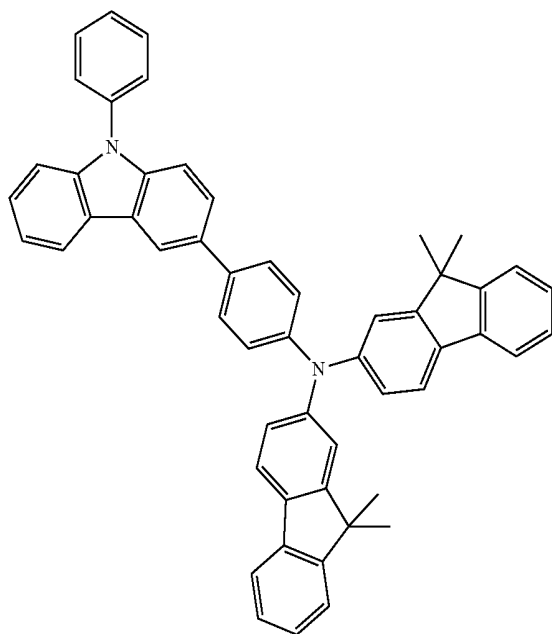


HT8

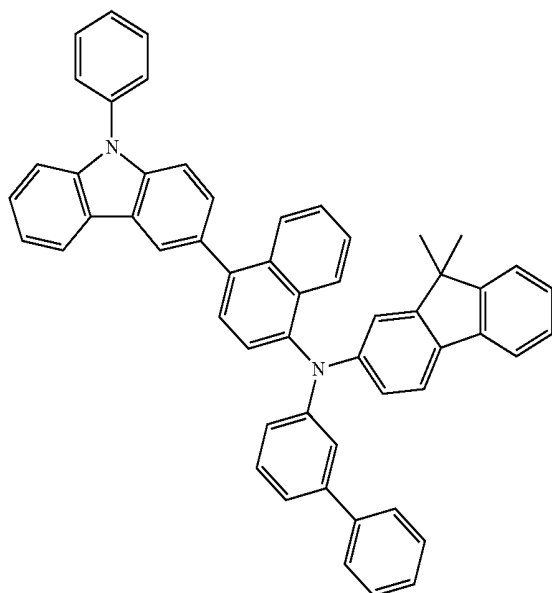


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HT9

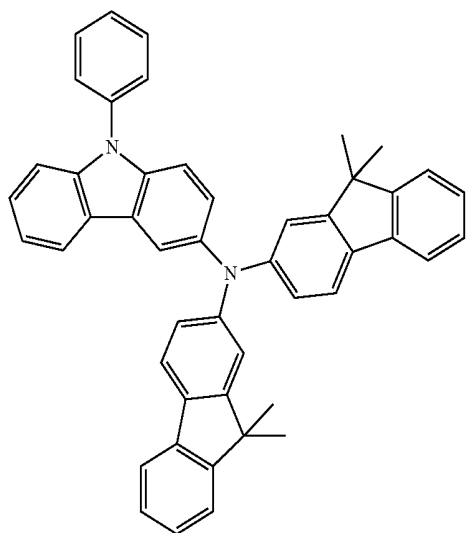


HT10

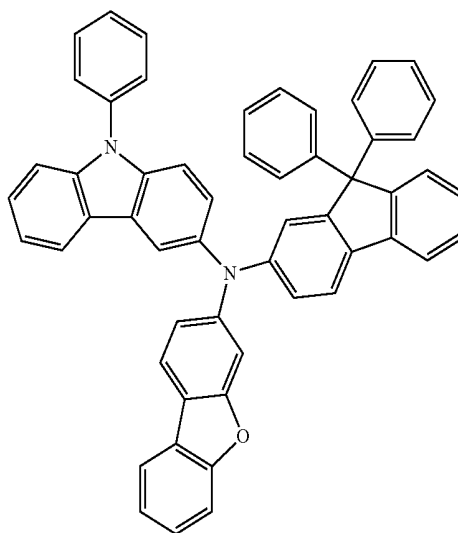


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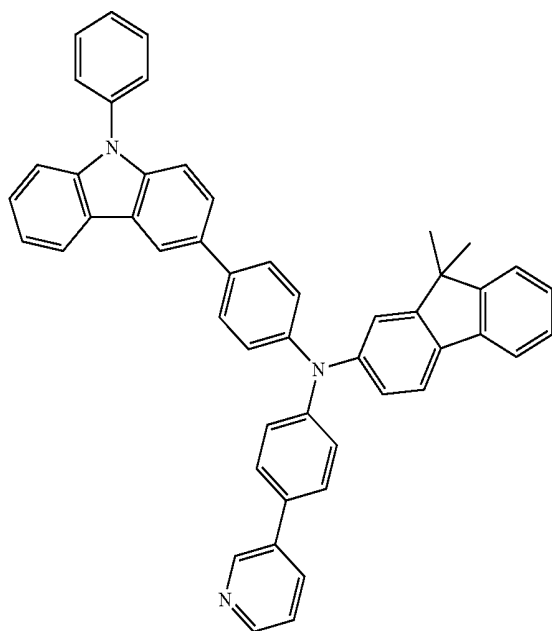
HT11



HT12

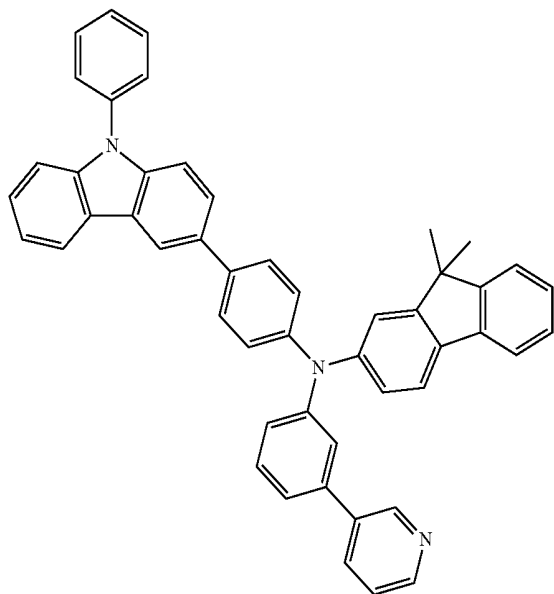


HT13

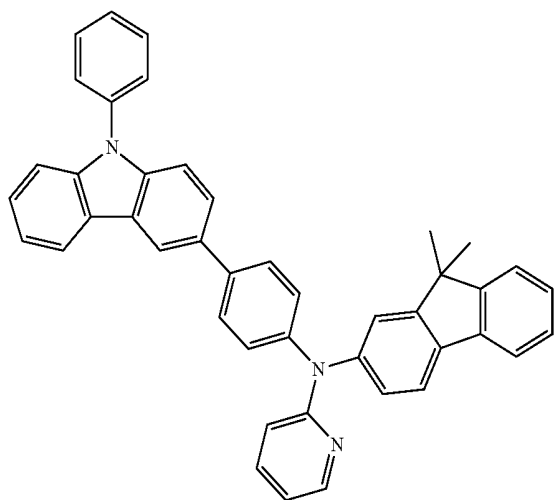


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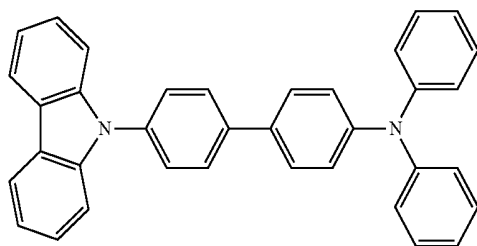
HT14



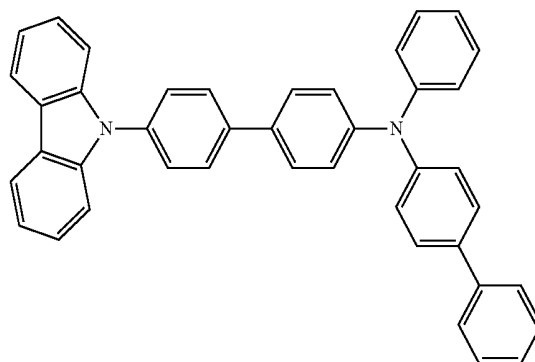
HT15



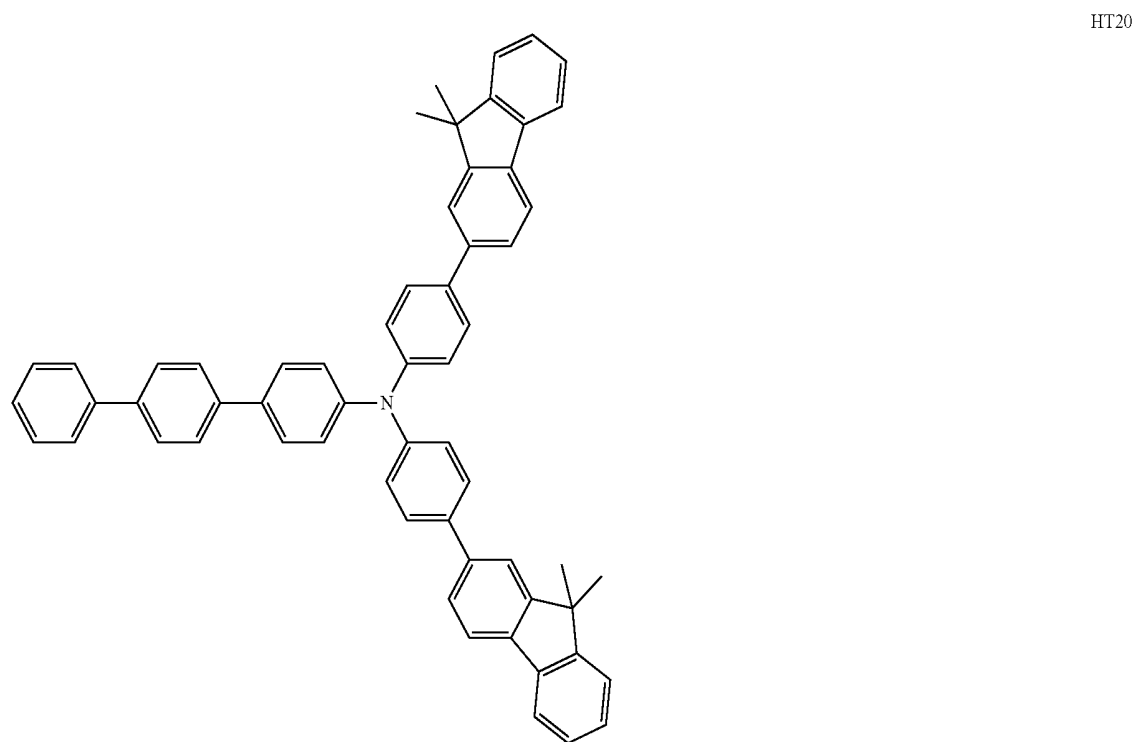
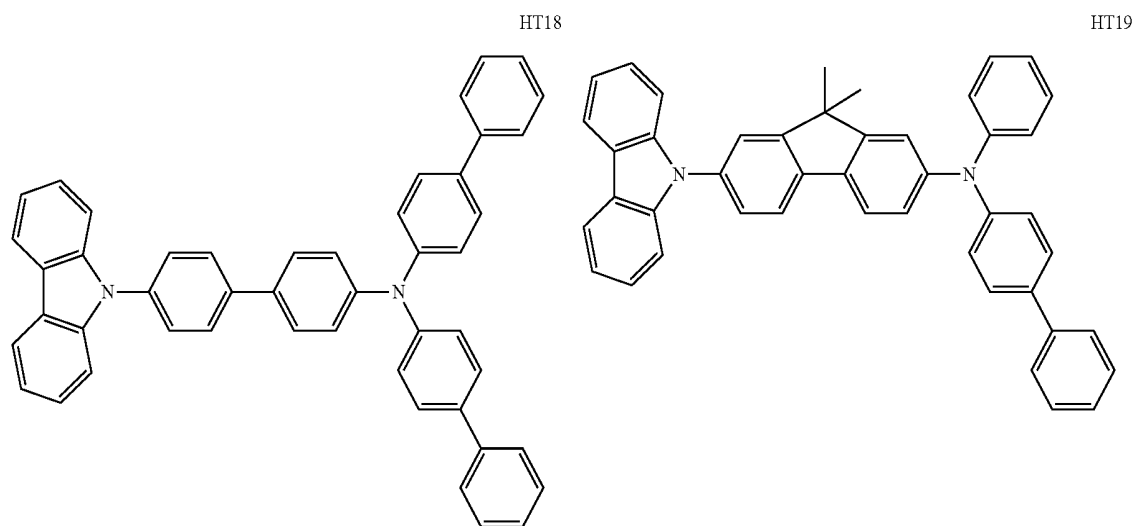
HT16



HT17

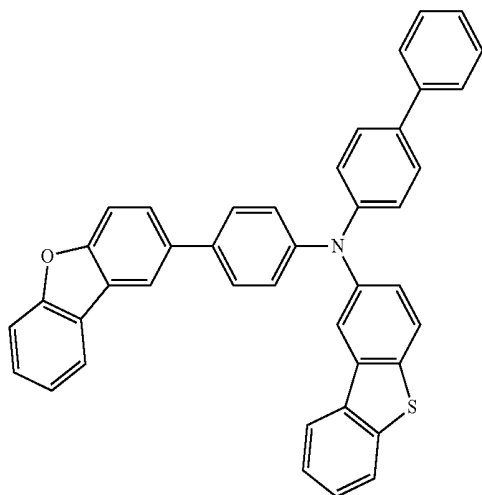


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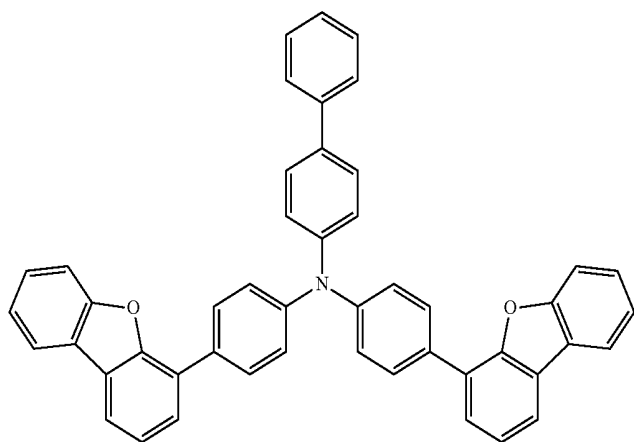


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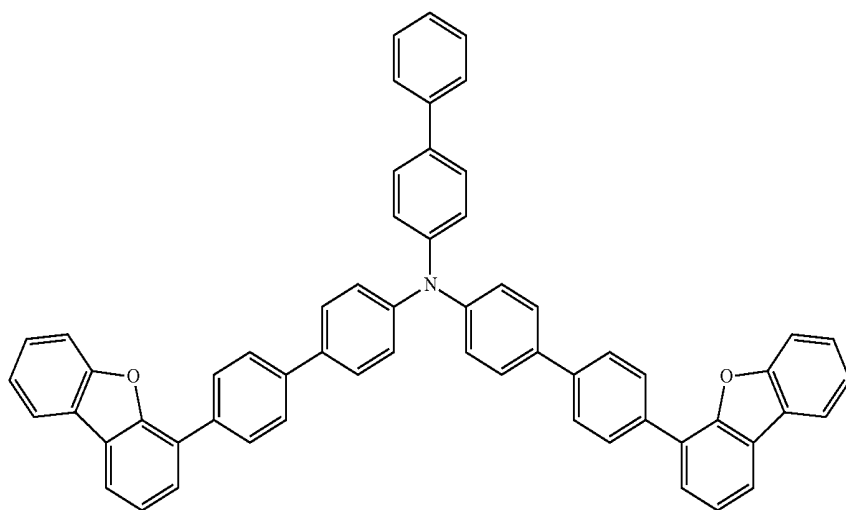
HT21



HT22

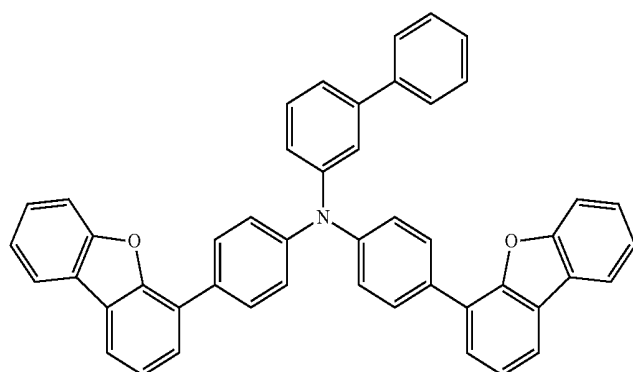


HT23



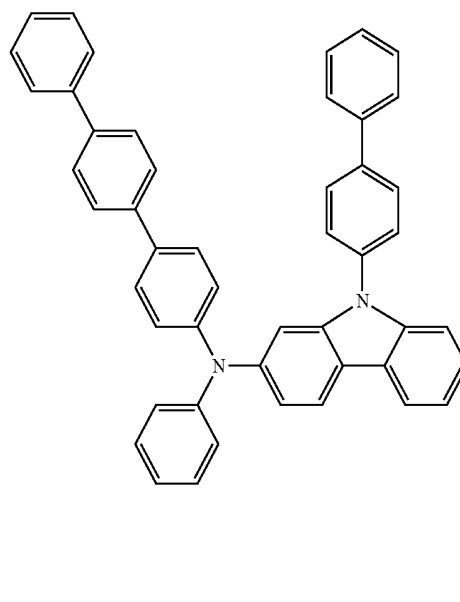
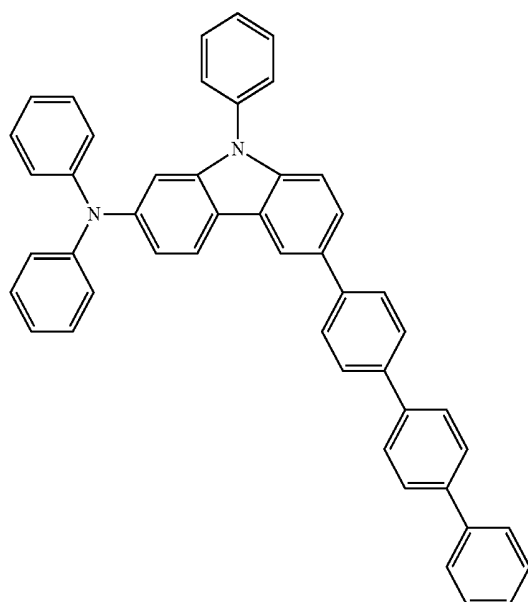
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HT24

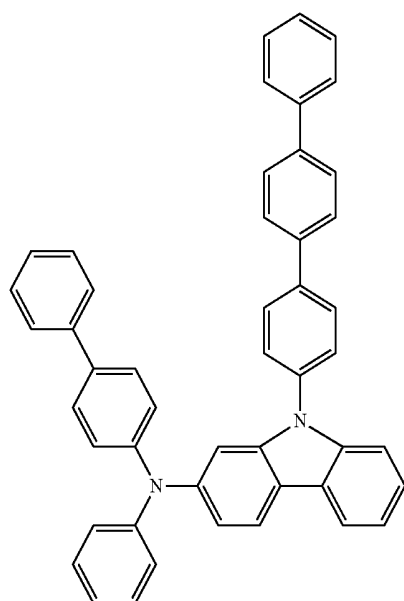


HT25

HT26

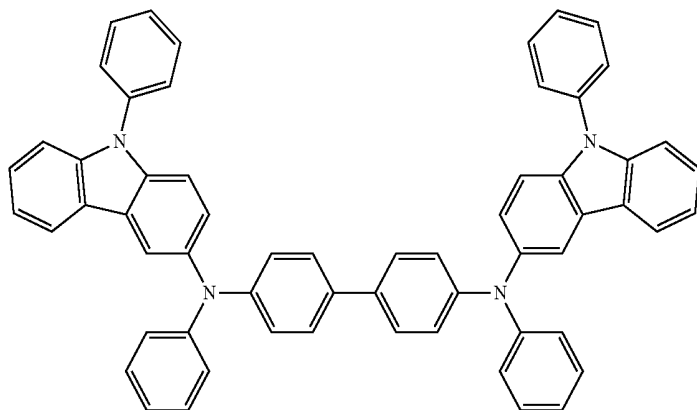


HT27

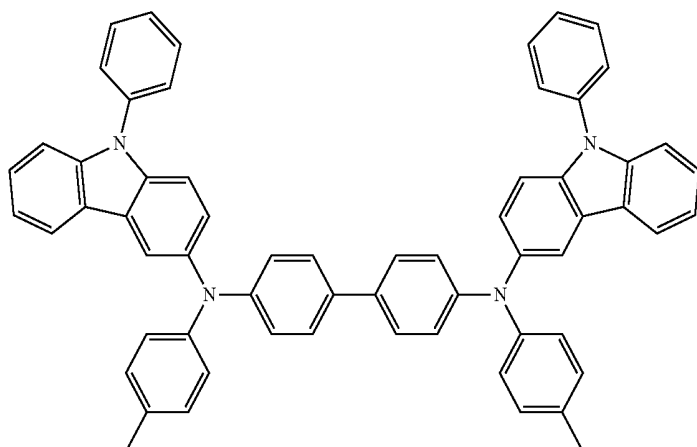


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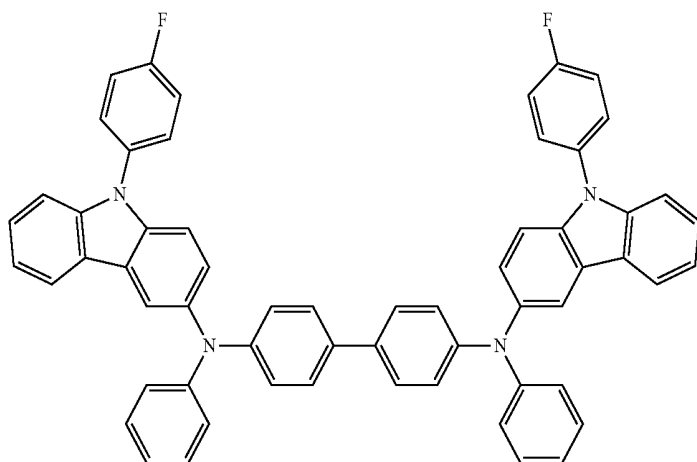
HT28



HT29

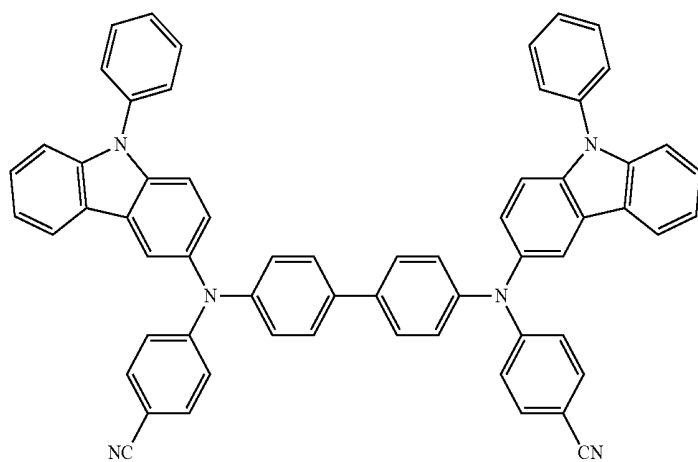


HT30

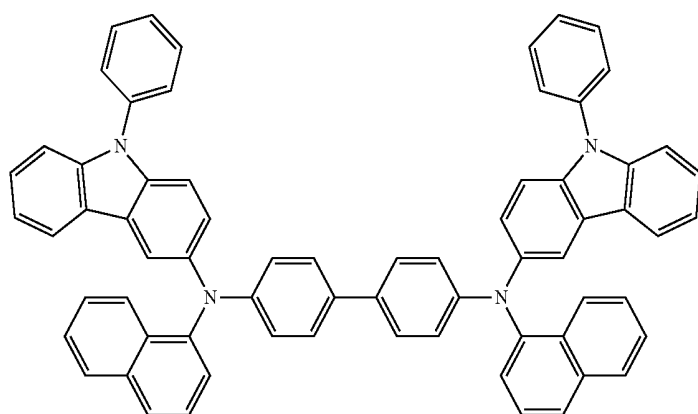


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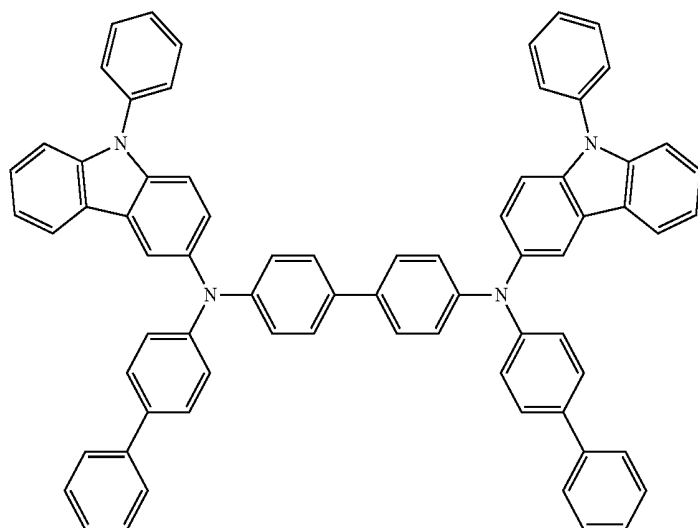
HT31



HT32

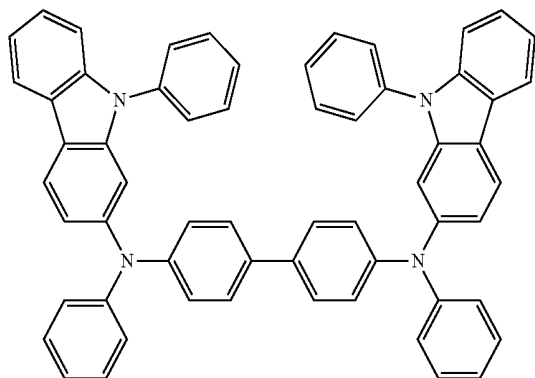


HT33

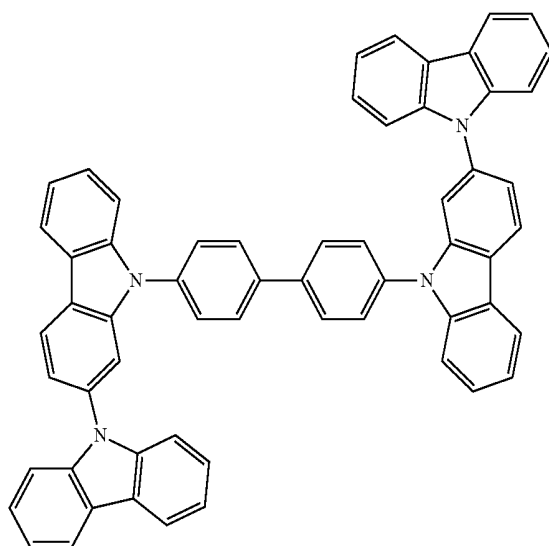


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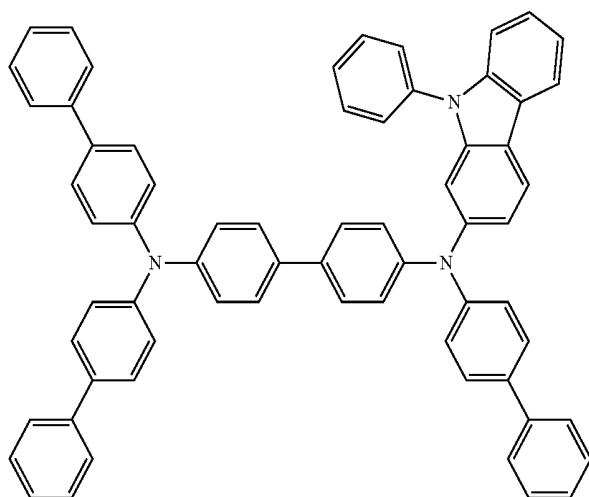
HT34



HT35

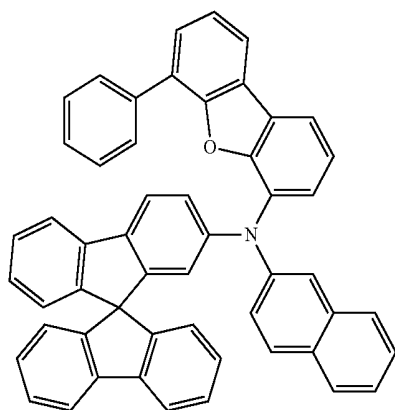
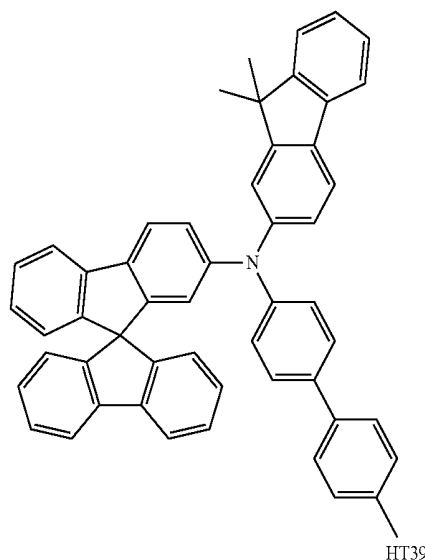
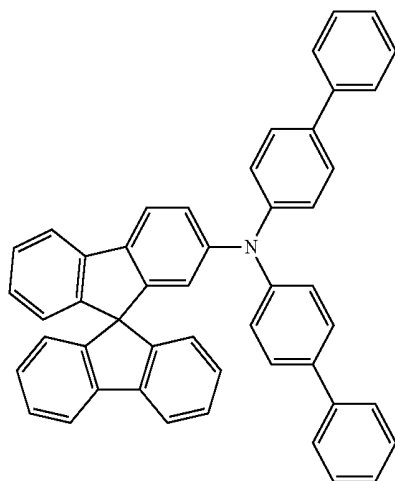


HT36



-continued
HT37

HT38



[0116] 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 at least one selected from a hole injection layer and a hole transport layer, the thickness of the hole injection layer may be about 100 Å to about 9,000 Å, and 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 each within these ranges, satisfactory hole transporting characteristics may be obtained without a substantial increase in driving voltage.

[0117] The emission auxiliary layer may increase light-emission efficiency by compensating for an optical resonance distance according to the wavelength of light emitted by an emission layer (e.g., adjusting the optical resonance distance to match the wavelength of light emitted from the emission layer). The electron blocking layer may block or reduce the flow of electrons from an electron transport region. The emission auxiliary layer and the electron blocking layer may include those materials as described above.

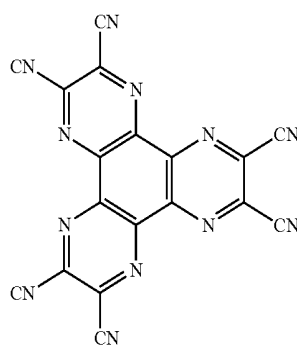
p-Dopant

[0118] The hole transport region may further include, in addition to these materials, a charge-generation material for the improvement of conductive properties. The charge-generation material may be homogeneously or non-homogeneously dispersed in the hole transport region.

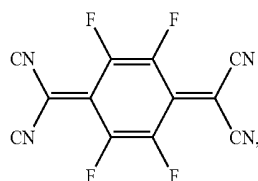
[0119] The charge-generation material may be, for example, a p-dopant.

[0120] The p-dopant may include at least one selected from a quinone derivative, a metal oxide, and a cyano group-containing compound, but embodiments of the present disclosure are not limited thereto.

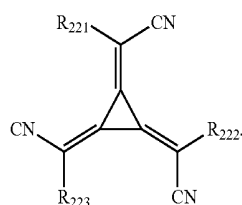
[0121] For example, the p-dopant may include at least one selected from a quinone derivative (such as a tetracyanoquinodimethane (TCNQ) and/or 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F4-TCNQ)); a metal oxide (such as a tungsten oxide and/or a molybdenum oxide); 1,4,5,8,9,11-hexaazatriphenylene-hexacarbonitrile (HAT-CN); and a compound represented by Formula 221, but embodiments of the present disclosure are not limited thereto:



<HAT-CN>



<F4-TCNQ>



Formula 221

[0122] In Formula 221,

[0123] R₂₂₁ to R₂₂₃ may each independently be selected from a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group,

[0124] wherein at least one selected from R₂₂₁ to R₂₂₃ may include at least one substituent selected from a cyano group, —F, —Cl, —Br, —I, a C₁-C₂₀ alkyl group substituted with —F, a C₁-C₂₀ alkyl group substituted with —Cl, a C₁-C₂₀ alkyl group substituted with —Br, and a C₁-C₂₀ alkyl group substituted with —I.

Emission Layer in Organic Layer 150

[0125] 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 various embodiments, the emission layer may have a stacked structure of two or more layers selected from a red emission layer, a green emission layer, and a blue emission layer, in which the two or more layers may contact each other or may be separated from each other. In one or more embodiments, the emission layer may include two or more materials selected from a red-light emission material, a green-light emission material, and a blue-light emission

material, in which the two or more materials may be mixed with each other in a single layer to thereby emit white light.

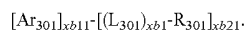
[0126] The emission layer may include a host and a dopant. The dopant may be at least one selected from a phosphorescent dopant and a fluorescent dopant.

[0127] The amount of the dopant in the emission layer may be 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.

[0128] The thickness of the emission layer may be about 100 Å to about 1,000 Å, and in some embodiments, about 200 Å to about 600 Å. When the thickness of the emission layer is within these ranges, excellent light-emission characteristics may be obtained without a substantial increase in driving voltage.

Host in Emission Layer

[0129] In one or more embodiments, the host may include a compound represented by Formula 301:



Formula 301

[0130] In Formula 301,

[0131] Ar₃₀₁ may be selected from a substituted or unsubstituted C₅-C₆₀ carbocyclic group and a substituted or unsubstituted C₁-C₆₀ heterocyclic group,

[0132] xb11 may be selected from 1, 2, and 3,

[0133] L₃₀₁ may be selected from a substituted or unsubstituted C₃-C₁₀ cycloalkylene group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkylene group, a substituted or unsubstituted C₃-C₁₀ cycloalkenylene group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenylene group, a substituted or unsubstituted C₆-C₆₀ arylene group, a substituted or unsubstituted C₁-C₆₀ heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0134] xb1 may be an integer selected from 0 to 5,

[0135] R₃₀₁ may be selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₂-C₆₀ alkenyl group, a substituted or unsubstituted C₂-C₆₀ alkynyl group, a substituted or unsubstituted C₁-C₆₀ alkoxy group, a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(Q₃₀₁)(Q₃₀₂)(Q₃₀₃), —N(Q₃₀₁)(Q₃₀₂), —B(Q₃₀₁)(Q₃₀₂), —C(=O)(Q₃₀₁), —S(=O)₂(Q₃₀₁), and —P(=O)(Q₃₀₁)(Q₃₀₂), and

[0136] xb21 may be an integer selected from 1 to 5,

[0137] wherein Q₃₀₁ to Q₃₀₃ may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, but embodiments of the present disclosure are not limited thereto.

[0138] In one or more embodiments, in Formula 301, Ar₃₀₁ may be selected from the group consisting of:

[0139] a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, and a dibenzothiophene group; and

[0140] a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, and a dibenzothiophene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂).

[0141] wherein Q₃₁ to Q₃₃ may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, but embodiments of the present disclosure are not limited thereto.

[0142] In Formula 301, when xb11 is two or more, two or more Ar₃₀₁(s) may be connected (e.g., coupled) via a single bond.

[0143] In one or more embodiments, the compound represented by Formula 301 may be represented by one selected from Formula 301-1 and 301-2:

a dibenzofuran, a naphthofuran, a benzonaphthofuran, a dinaphthofuran, a thiophene, a benzothiophene, a dibenzothiophene, a naphthothiophene, a benzonaphthothiophene, and a dinaphthothiophene,

[0146] X₃₀₁ may be selected from O, S, and N-[(L₃₀₄)_{xb4}-R₃₀₄],

[0147] R₃₁₁ to R₃₁₄ may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂),

[0148] xb22 and xb23 may each independently be selected from 0, 1, and 2,

[0149] L₃₀₁, xb1, R₃₀₁, and Q₃₁ to Q₃₃ may each independently be the same as described above,

[0150] L₃₀₂ to L₃₀₄ may each independently be the same as described above in connection with L₃₀₁,

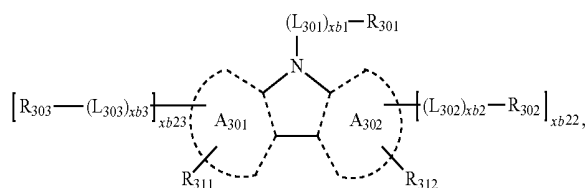
[0151] xb2 to xb4 may each independently be the same as described above in connection with xb1, and

[0152] R₃₀₂ to R₃₀₄ may each independently be the same as described above in connection with R₃₀₁.

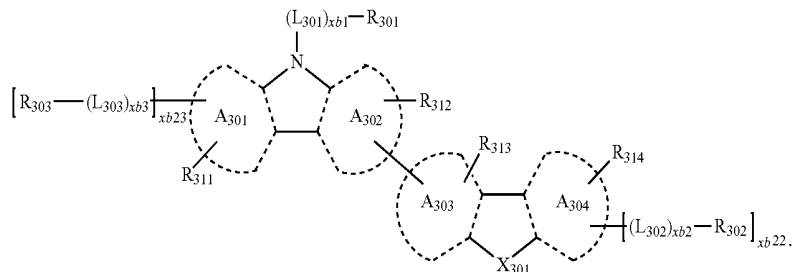
[0153] For example, in Formulae 301, 301-1, and 301-2, L₃₀₁ to L₃₀₄ may each independently be selected from the group consisting of:

[0154] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylenylene group, a fluoranthenylenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylenylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylenylene group, a pentacenylenylene group, a thiophenylenylene group, a furanylenylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a ben-

Formula 301-1



Formula 301-2



[0144] In Formulae 301-1 to 301-2,

[0145] A₃₀₁ to A₃₀₄ may each independently be selected from a benzene, a naphthalene, a phenanthrene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a pyridine, a pyrimidine, an indene, a fluorene, a spiro-bifluorene, a benzofluorene, a dibenzofluorene, an indole, a carbazole, a benzocarbazole, a dibenzocarbazole, a furan, a benzofuran,

zofuranylene group, a benzothiophenylenylene group, a dibenzofuranylene group, a benzothiophenylenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, a pyridinylenylene group, an imidazolylenylene group, a pyrazolylenylene group, a thiazolylenylene group, an isothiazolylenylene group, an oxazolylenylene group, an isoxazolylenylene group, a thiadiazolylenylene group, an oxadiazolylenylene group,

group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolylene group; and

[0155] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, a pyridinylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isoxazolylene group, a thiadiazolylene group, an oxadiazolylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a

azolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an azacarbazolyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂),

[0156] wherein Q₃₁ to Q₃₃ may each independently be the same as described above.

[0157] In one or more embodiments, in Formulae 301, 301-1, and 301-2, R₃₀₁ to R₃₀₄ may each independently be selected from the group consisting of:

[0158] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group; and

[0159] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a

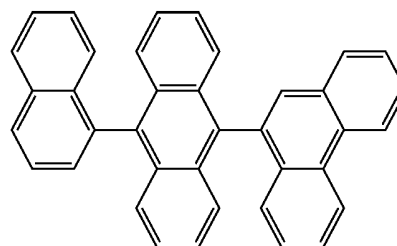
C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an azacarbazolyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂).

[0160] wherein Q₃₁ to Q₃₃ may each independently be the same as described above.

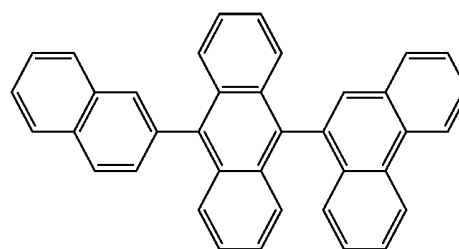
[0161] In one or more embodiments, the host may include an alkaline earth metal complex. For example, the host may be selected from a beryllium (Be) complex (for example, Compound H55), a Mg complex, and a Zn complex.

[0162] The host may include at least one selected from 9,10-di(2-naphthyl)anthracene (ADN), 2-methyl-9,10-bis(naphthalen-2-yl)anthracene (MADN), 9,10-di-(2-naphthyl)-2-t-butyl-anthracene (TBADN), 4,4'-bis(N-carbazolyl)-1,1'-biphenyl (CBP), 1,3-di-9-carbazolylbenzene (mCP), 1,3,5-tri(carbazol-9-yl)benzene (TCP), and Compounds H1 to H55, but embodiments of the present disclosure are not limited thereto:

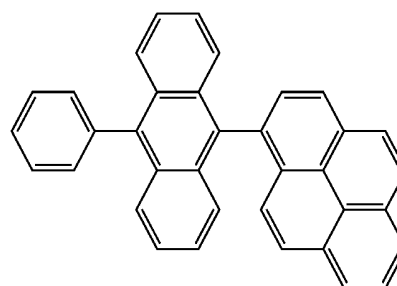
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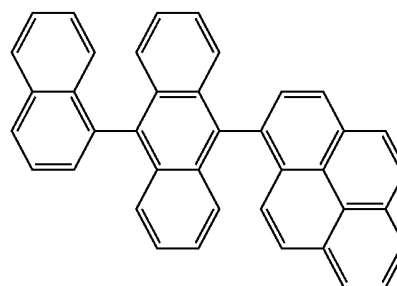
H3



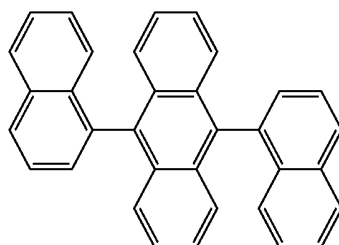
H4



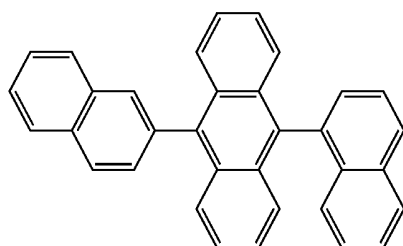
H5



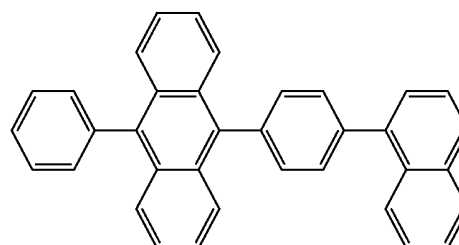
H6



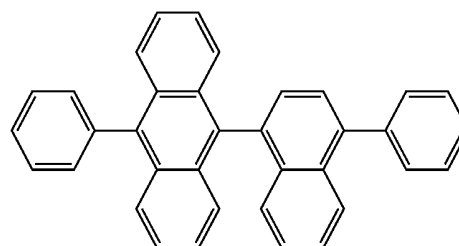
H1



H2

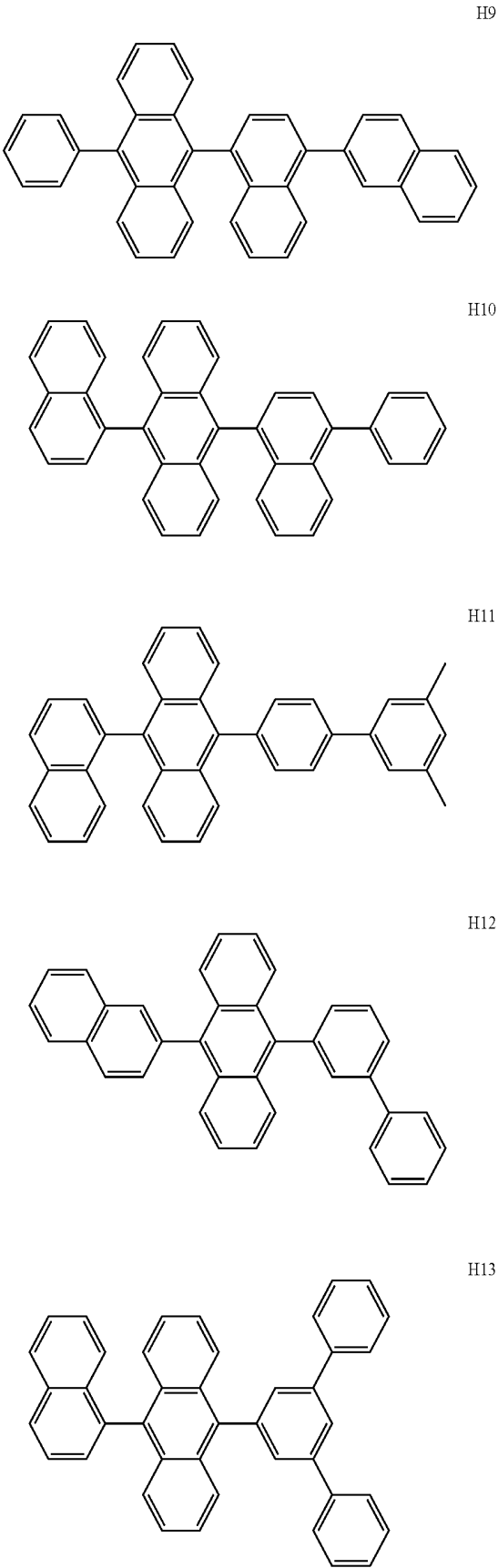


H7

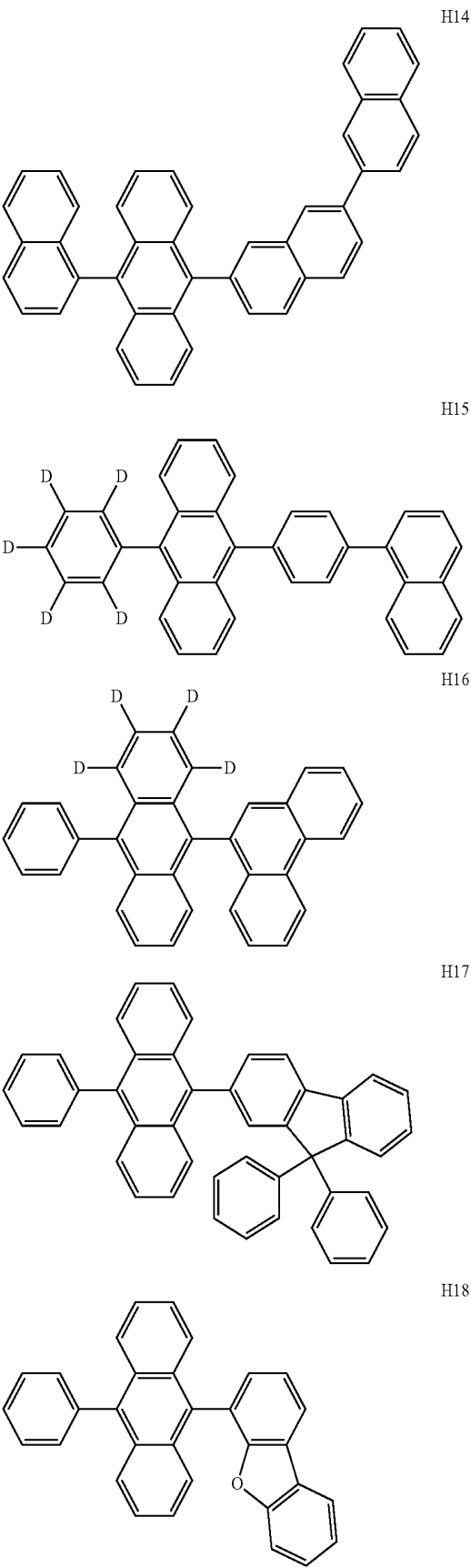


H8

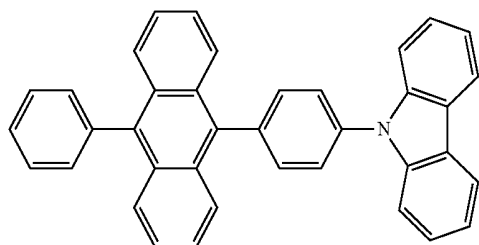
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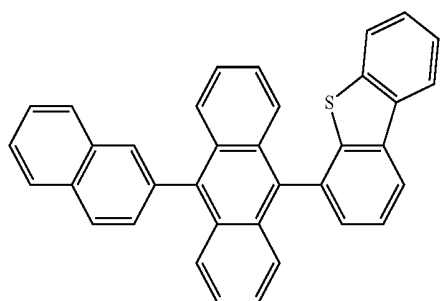
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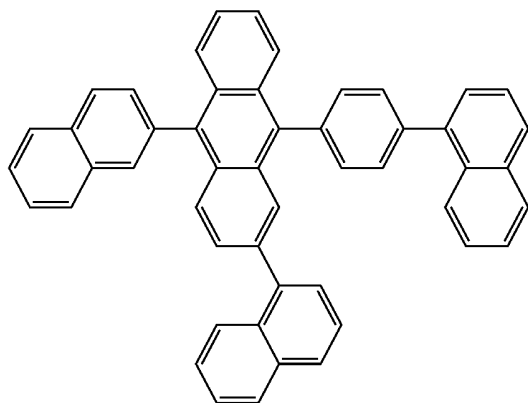
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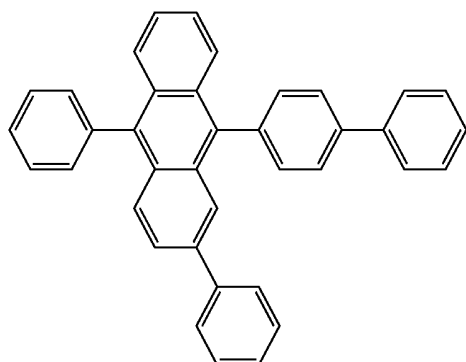
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H20

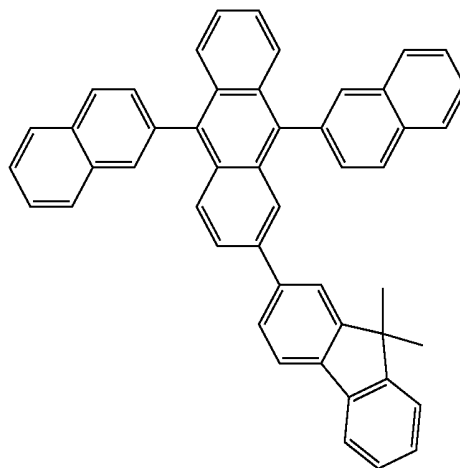


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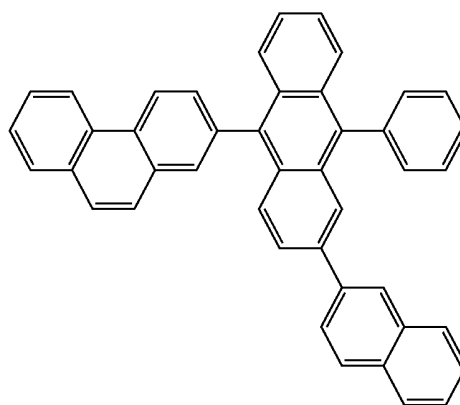


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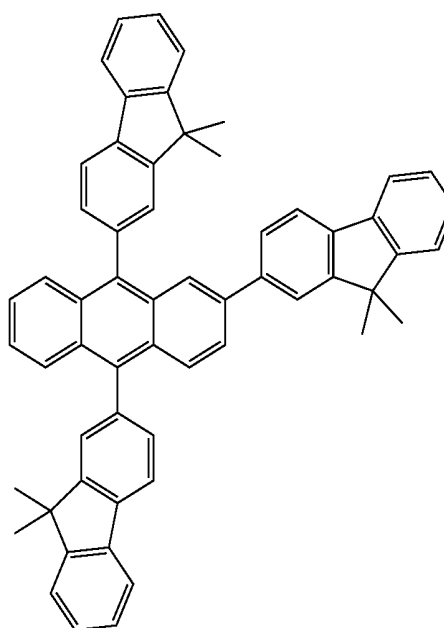
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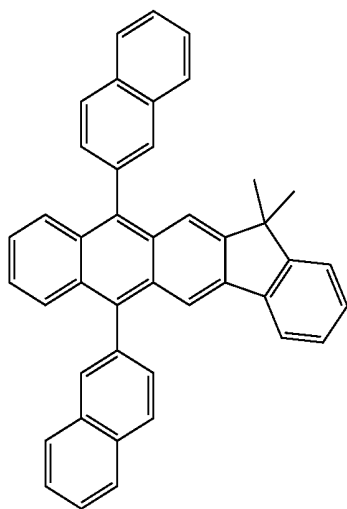
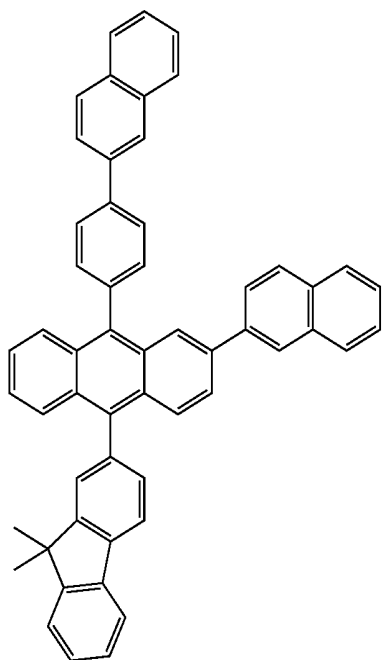
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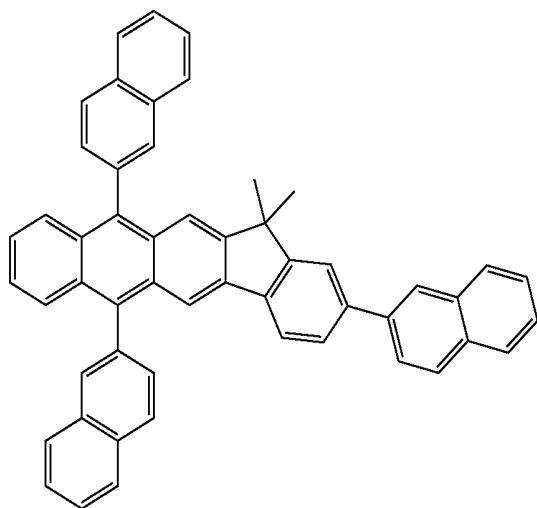
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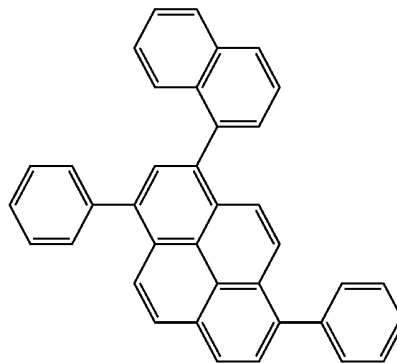
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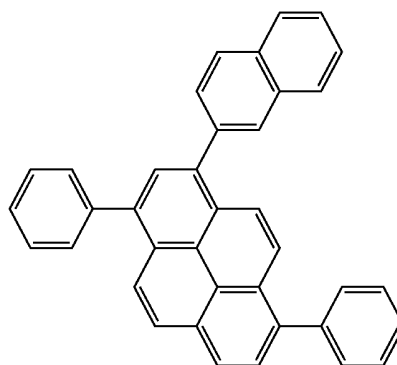
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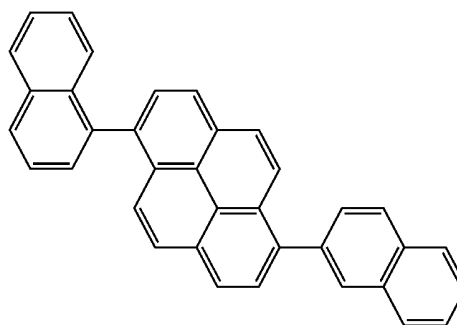
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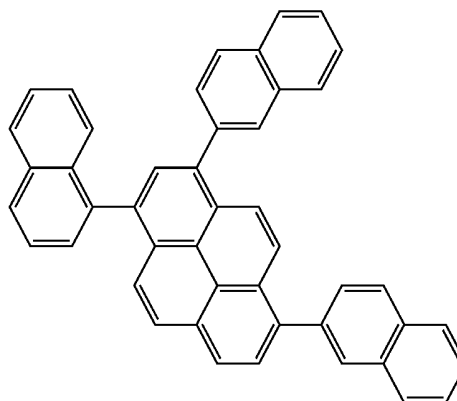
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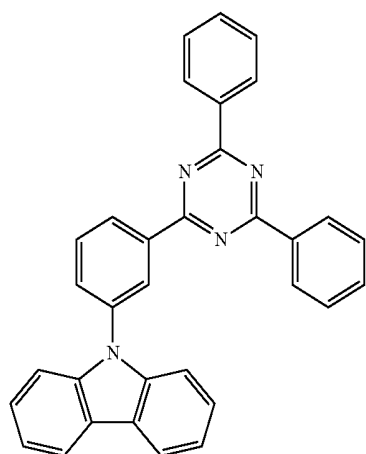
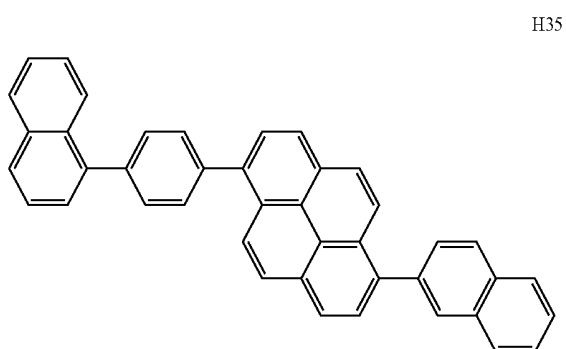
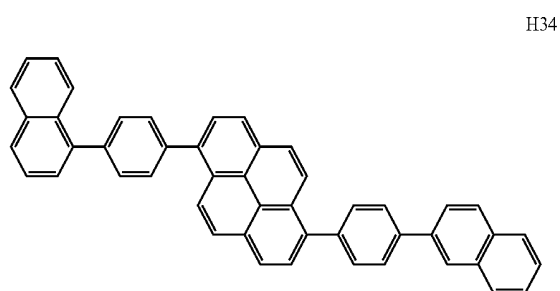
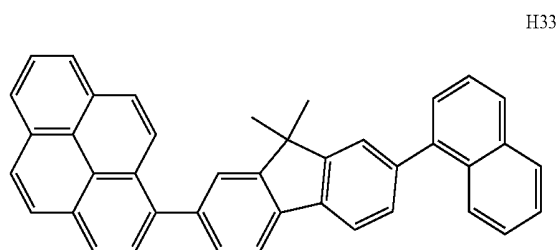
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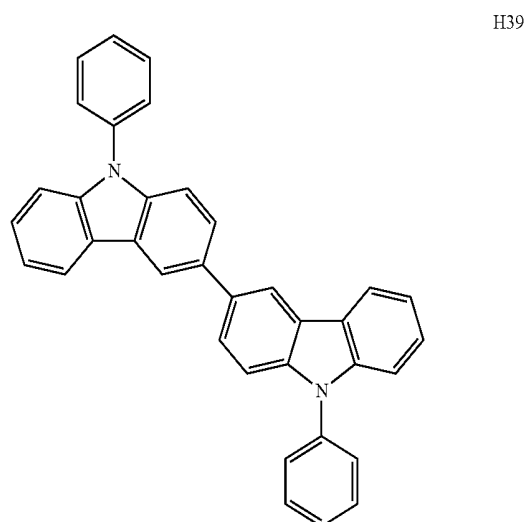
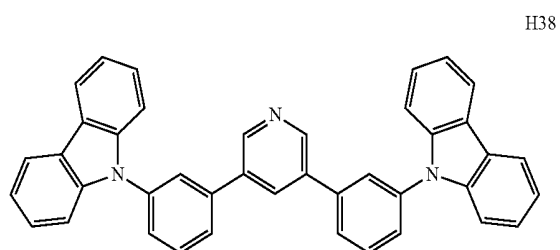
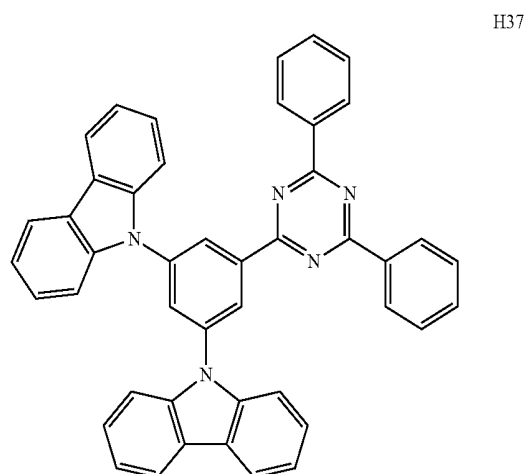
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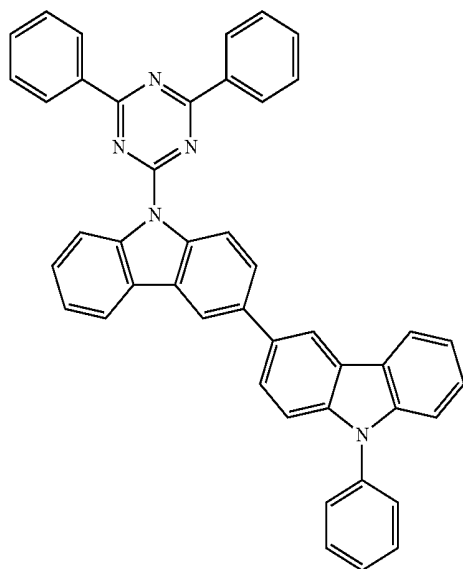
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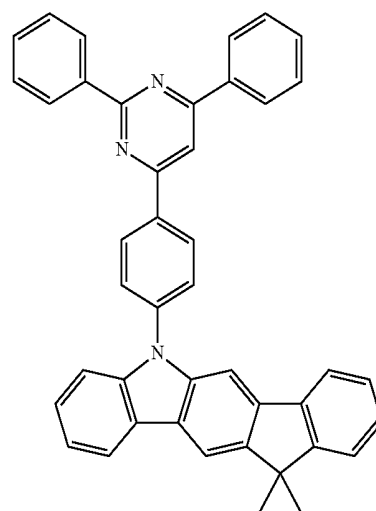


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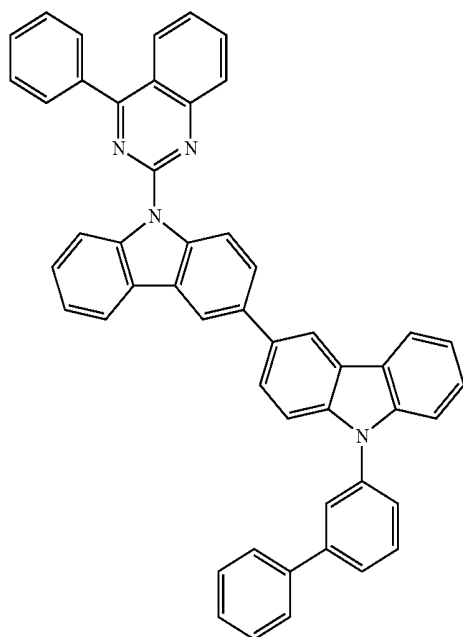


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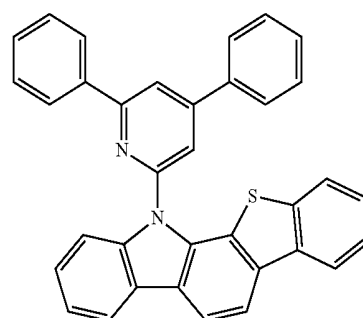
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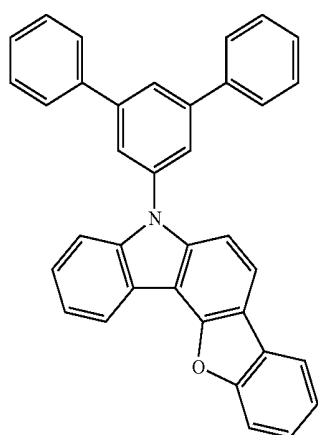
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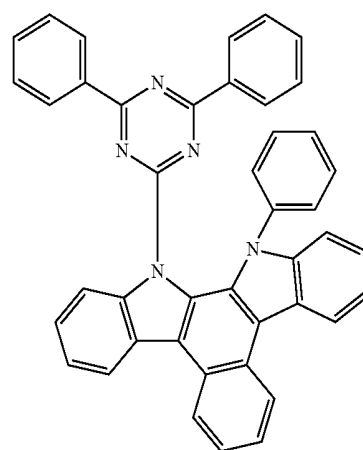
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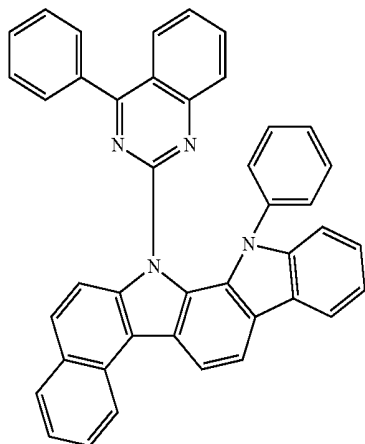
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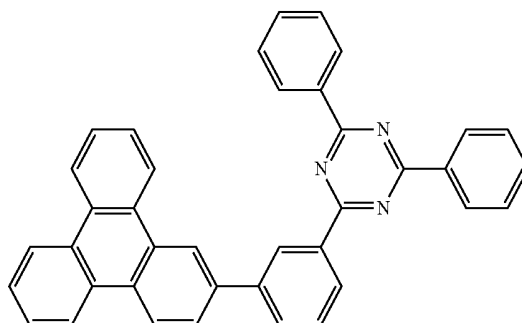
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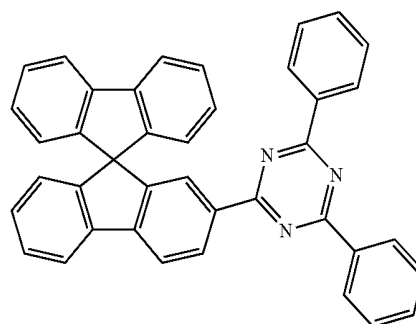


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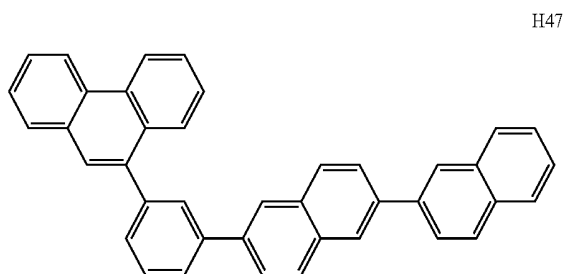
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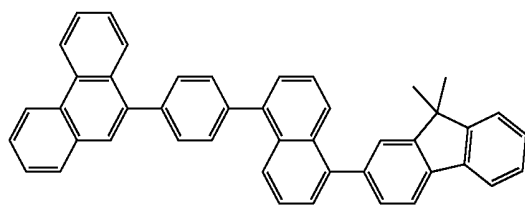
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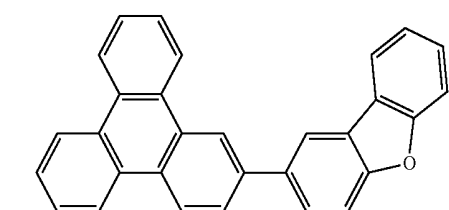
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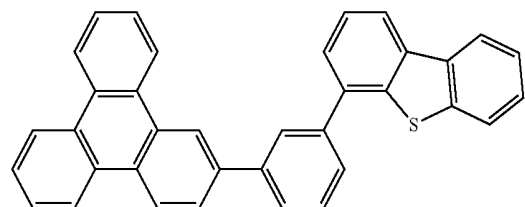
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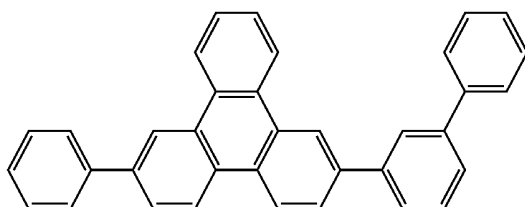
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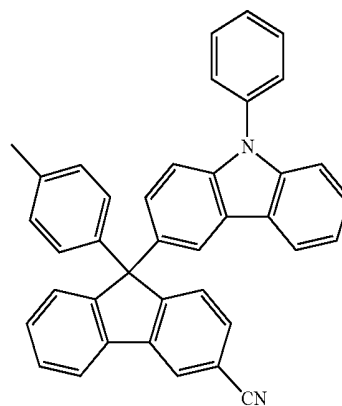
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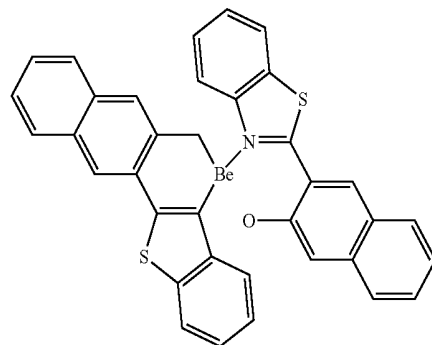
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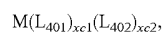
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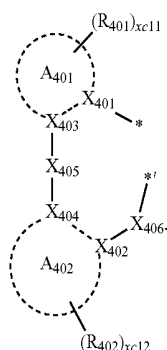
Phosphorescent Dopant in Organic Layer **150**

[0163] The phosphorescent dopant may include an organometallic complex represented by Formula 401:



Formula 401

Formula 402



[0164] In Formulae 401 and 402,

[0165] M may be selected from iridium (Ir), platinum (Pt), palladium (Pd), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), rhodium (Rh), and thulium (Tm),

[0166] L_{401} may be a ligand represented by Formula 402,

[0167] xc1 may be selected from 1, 2, and 3,

[0168] when xc1 is two or more, two or more L_{401} (s) may be identical to or different from each other,

[0169] L_{402} may be an organic ligand,

[0170] xc2 may be an integer selected from 0 to 4,

[0171] when xc2 is two or more, two or more L_{402} (s) may be identical to or different from each other,

[0172] X_{401} to X_{404} may each independently be selected from nitrogen (N) and carbon (C),

[0173] X_{401} and X_{403} may be connected (e.g., coupled) via a single bond or a double bond, and X_{402} and X_{404} may be connected (e.g., coupled) via a single bond or a double bond,

[0174] A_{401} and A_{402} may each independently be selected from a C_5 - C_{60} carbocyclic group and a C_1 - C_{60} heterocyclic group,

[0175] X_{405} may be selected from a single bond, *O , *S , $^*C(=O)$, $^*N(Q_{411})$, $^*C(Q_{411})$, $^*C(Q_{412})$, $^*C(Q_{411})=C(Q_{412})$, $^*C(Q_{411})$, and $^*C(Q_{411})$, wherein Q_{411} and Q_{412} may each independently be selected from hydrogen, deuterium, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group,

[0176] X_{406} may be selected from a single bond, O, and S,

[0177] R_{401} and R_{402} may each independently be selected from hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1 - C_{20} alkyl group, a substituted or unsubstituted C_1 - C_{20} alkoxy group, a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6 - C_{60} aryl group, a substituted or unsubstituted C_6 - C_{60} aryloxy group, a substituted or unsubstituted C_6 - C_{60} arylthio group, a substituted or unsubstituted C_1 - C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, $-Si(Q_{401})(Q_{402})(Q_{403})$, $-N(Q_{401})(Q_{402})$, $-B(Q_{401})(Q_{402})$, $-C(=O)(Q_{401})$, $-S(=O)_2(Q_{401})$, and $-P(=O)(Q_{401})(Q_{402})$, wherein Q_{401} to Q_{403}

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

[0178] xc11 and xc12 may each independently be an integer selected from 0 to 10, and

[0179] in Formula 402, * and * may each independently indicate a binding site to M in Formula 401.

[0180] In one or more embodiments, in Formula 402, A_{401} and A_{402} may each independently be selected from a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, an indene group, a pyrrole group, a thiophene group, a furan group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a quinoxaline group, a quinazoline group, a carbazole group, a benzimidazole group, a benzofuran group, a benzothiophene group, an isobenzothiophene group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a dibenzofuran group, and a dibenzothiophene group.

[0181] In one or more embodiments, in Formula 402, i) X_{401} may be nitrogen and X_{402} may be carbon, or ii) both X_{401} and X_{402} may be nitrogen.

[0182] In one or more embodiments, in Formula 402, R_{401} and R_{402} may each independently be selected from the group consisting of:

[0183] hydrogen, deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, and C_1 - C_{20} alkoxy group;

[0184] a C_1 - C_{20} alkyl group and a C_1 - C_{20} alkoxy group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a phenyl group, a naphthyl group, a cyclopentyl group, a cyclohexyl group, an adamantyl group, a norbornanyl group, and a norbornenyl group;

[0185] a cyclopentyl group, a cyclohexyl group, an adamantyl group, a norbornanyl group, a norbornenyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

[0186] a cyclopentyl group, a cyclohexyl group, an adamantyl group, a norbornanyl group, a norbornenyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, $-F$, $-Cl$, $-Br$, $-I$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, an adamantyl group, a norbornanyl group, a norbornenyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a

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

[0187] $-\text{Si}(\text{Q}_{401})(\text{Q}_{402})(\text{Q}_{403})$, $-\text{N}(\text{Q}_{401})(\text{Q}_{402})$, $-\text{B}(\text{Q}_{401})(\text{Q}_{402})$, $-\text{C}(=\text{O})(\text{Q}_{401})$, $-\text{S}(=\text{O})_2(\text{Q}_{401})$, and $-\text{P}(=\text{O})(\text{Q}_{401})(\text{Q}_{402})$,

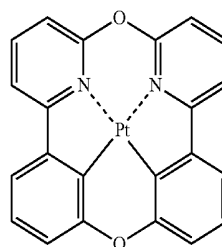
[0188] wherein Q_{401} to Q_{403} may each independently be selected from a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a biphenyl group, and a naphthyl group.

[0189] In one or more embodiments, in Formula 401, when x_1 is two or more, two or more L_{401} (s) may be optionally connected (e.g., coupled) through a linking group (for example, X_{407}), or two A_{402} (s) may be optionally connected (e.g., coupled) through a linking group (for example, X_{408}) (see Compounds PD1 to PD4 and PD7). X_{407} and X_{408} may each independently be selected from a single bond, $^*\text{O}^*$, $^*\text{S}^*$, $^*\text{C}(=\text{O})^*$, $^*\text{N}(\text{Q}_{413})^*$, $^*\text{C}(\text{Q}_{413})(\text{Q}_{414})^*$, and $^*\text{C}(\text{Q}_{413})=\text{C}(\text{Q}_{414})^*$ (wherein Q_{413} and Q_{414} may each independently be selected from hydrogen, deuterium, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group), but embodiments of the present disclosure are not limited thereto.

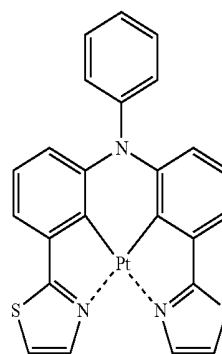
[0190] In Formula 401, L_{402} may be a monovalent, divalent, or trivalent organic ligand. For example, L_{402} may be selected from a halogen atom, a diketone (for example, an acetylacetonate), a carboxylic acid (for example, a picolinate), $-\text{C}(=\text{O})$, an isonitrile, $-\text{CN}$, and a phosphorus ligand (for example, a phosphine and/or a phosphite), but embodiments of the present disclosure are not limited thereto.

[0191] In one or more embodiments, the phosphorescent dopant may be selected from, for example, Compounds PD1 to PD25, but embodiments of the present disclosure are not limited thereto:

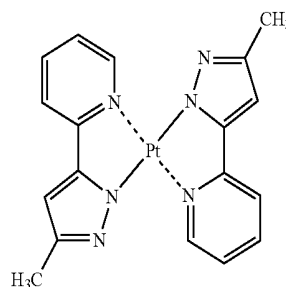
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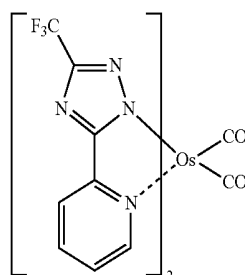
PD3



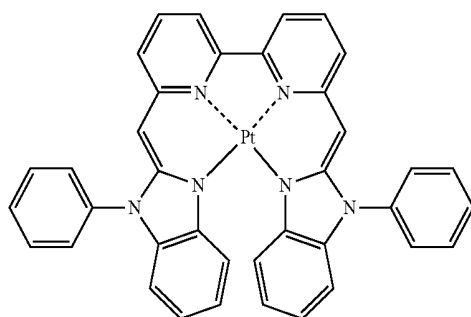
PD4



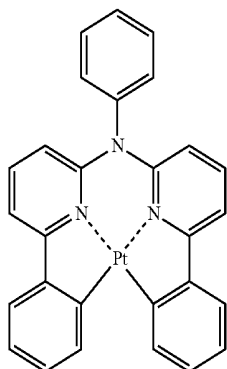
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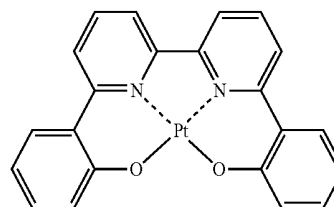
PD6



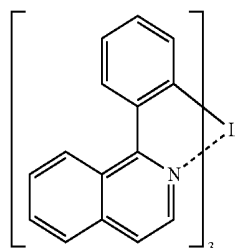
PD1



PD2

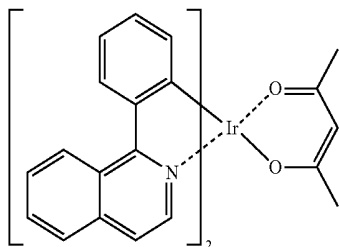


PD7



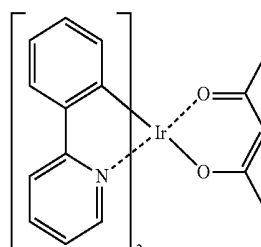
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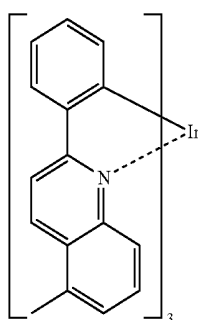


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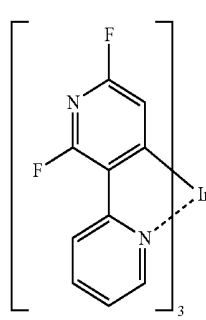
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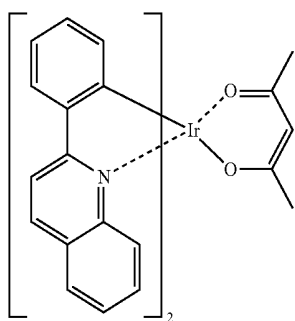
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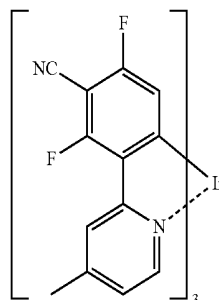
PD10



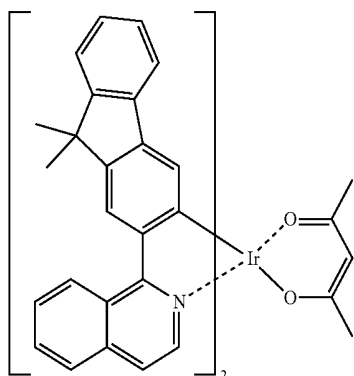
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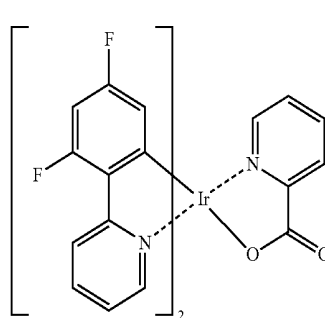
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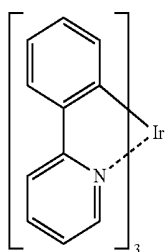
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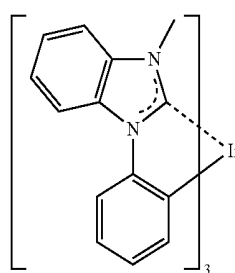
PD12



PD17

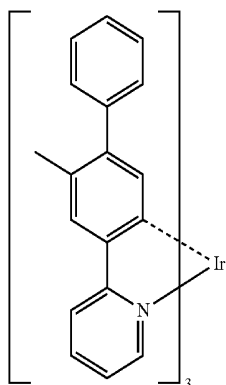
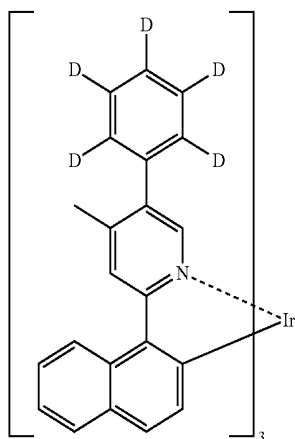
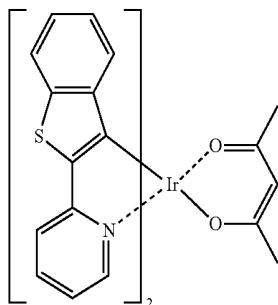
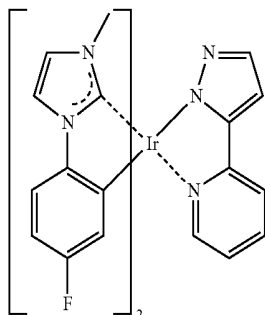


PD13



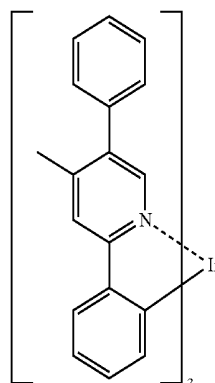
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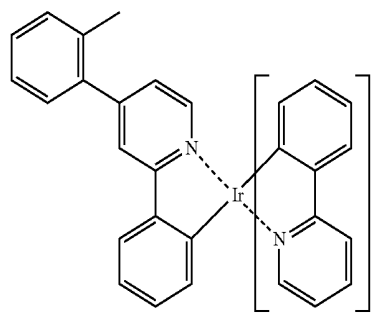
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PD19



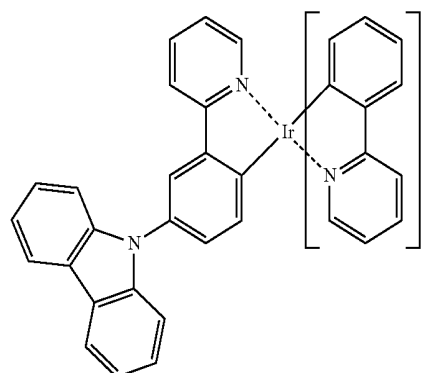
PD23

PD20



PD24

PD21



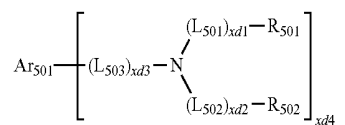
PD25

Fluorescent Dopant in Emission Layer

[0192] The fluorescent dopant may include a compound represented by Formula 501:

PD22

Formula 501



[0193] In Formula 501,

[0194] Ar_{501} may be selected from a substituted or unsubstituted $\text{C}_5\text{-C}_{60}$ carbocyclic group and a substituted or unsubstituted $\text{C}_1\text{-C}_{60}$ heterocyclic group,

[0195] L_{501} to L_{503} may each independently be selected from a substituted or unsubstituted $\text{C}_3\text{-C}_{10}$ cycloalkylene group, a substituted or unsubstituted $\text{C}_1\text{-C}_{10}$ heterocycloalkylene group, a substituted or unsubstituted $\text{C}_3\text{-C}_{10}$

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.

[0196] $xd1$ to $xd3$ may each independently be an integer selected from 0 to 3,

[0197] R_{501} and R_{502} may each independently be selected from a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6 - C_{60} aryl group, a substituted or unsubstituted C_6 - C_{60} aryloxy group, a substituted or unsubstituted C_6 - C_{60} arylthio group, a substituted or unsubstituted C_1 - C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, and

[0198] $xd4$ may be an integer selected from 1 to 6.

[0199] In one or more embodiments, in Formula 501, Ar_{501} may be selected from the group consisting of:

[0200] a naphthalene group, a heptalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, and an indenophenanthrene group; and

[0201] a naphthalene group, a heptalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, and an indenophenanthrene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0202] In one or more embodiments, in Formula 501, L_{501} to L_{503} may each independently be selected from the group consisting of:

[0203] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylenylene group, a fluoranthenylenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylenylene group, a pentacenylenylene group, a thiophenylenylene group, a furanylenylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylenylene group, a benzothiophenylenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, and a pyridinylenylene group; and

[0204] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylenylene group, a fluoranthenylenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylenylene group, a pentacenylenylene group, a thiophenylenylene group, a furanylenylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylenylene group, a benzothiophenylenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, and a pyridinylenylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a

nylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylenylene group, a fluoranthenylenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylenylene group, a hexacenylenylene group, a pentacenylenylene group, a thiophenylenylene group, a furanylenylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylenylene group, a benzothiophenylenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, and a pyridinylenylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group.

[0205] In one or more embodiments, in Formula 501, R_{501} and R_{502} may each independently be selected from the group consisting of:

[0206] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group; and

[0207] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a

fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, and $-\text{Si}(\text{Q}_{31})(\text{Q}_{32})(\text{Q}_{33})$.

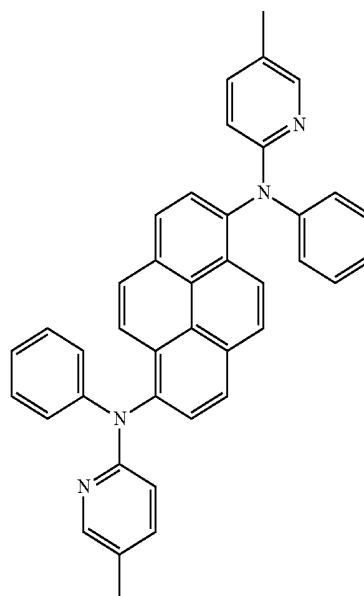
[0208] wherein Q_{31} to Q_{33} may each independently be selected from a C_1 - C_{10} alkyl group, a C_1 - C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0209] In one or more embodiments, in Formula 501, xd4 may be two, but embodiments of the present disclosure are not limited thereto.

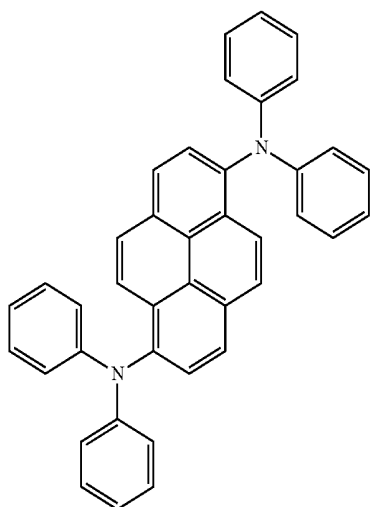
[0210] For example, the fluorescent dopant may be selected from Compounds FD1 to FD22:

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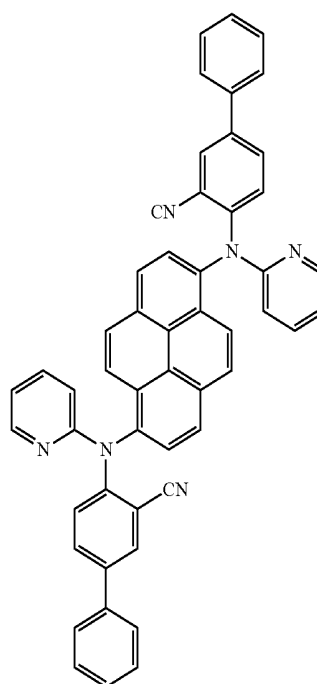
FD3



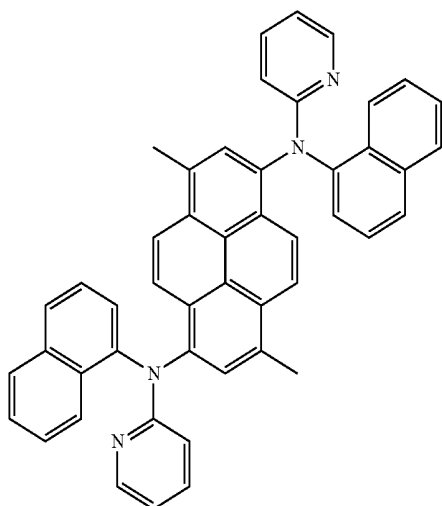
FD1



FD4

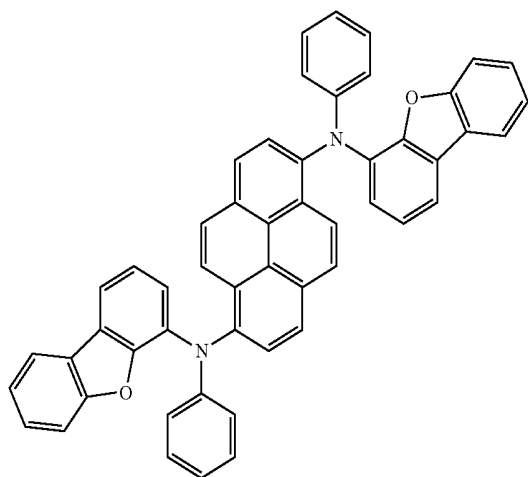


FD2



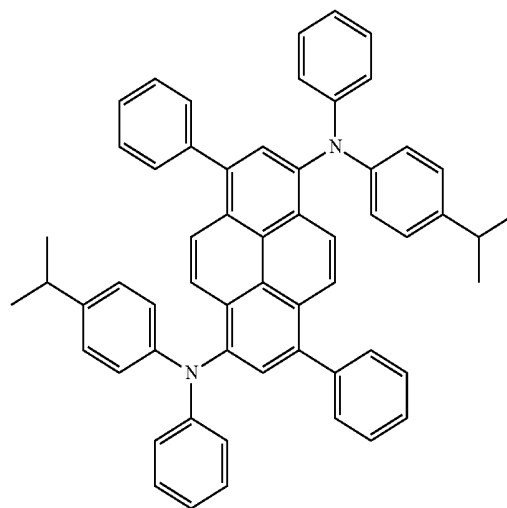
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FD5

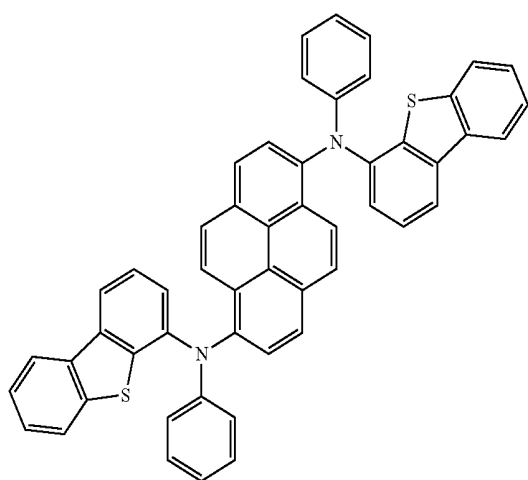


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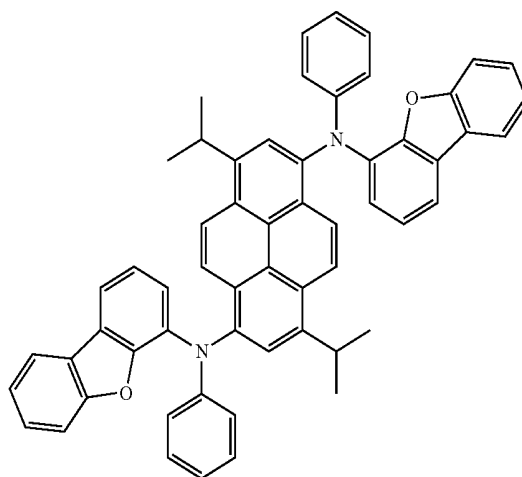
FD8



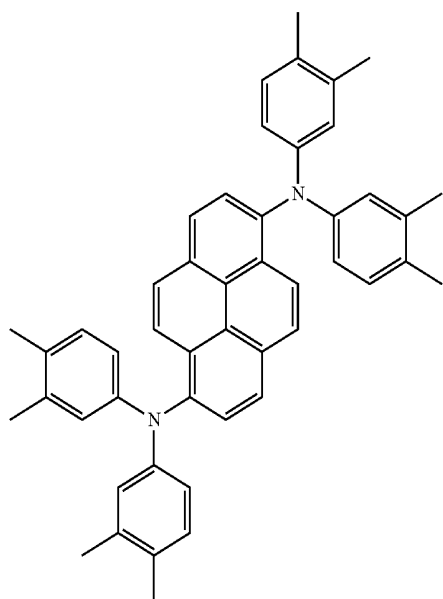
FD6



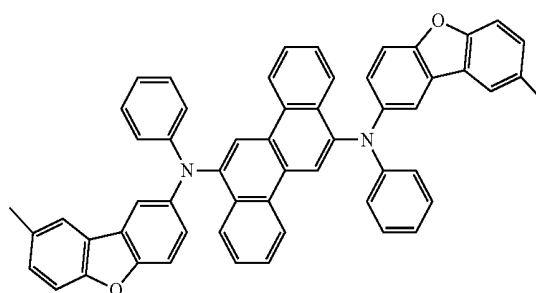
FD9



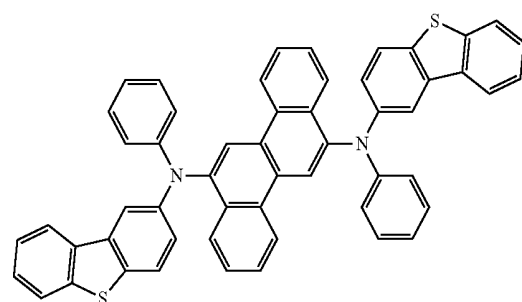
FD7



PD10

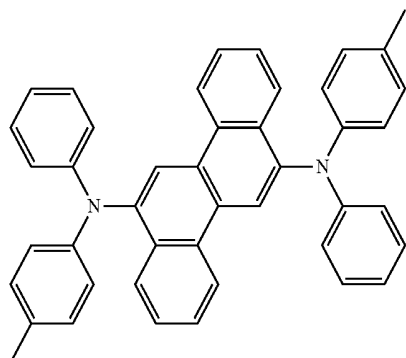


PD11



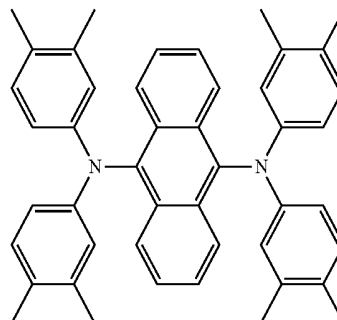
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PD12



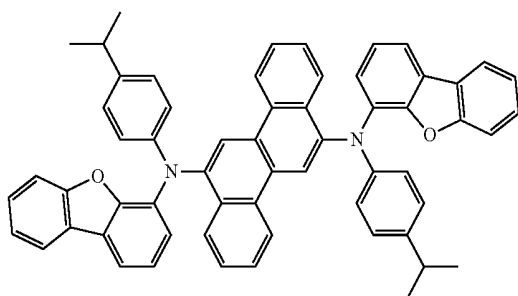
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FD17

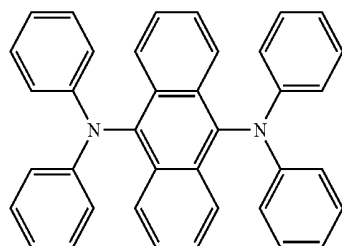


FD18

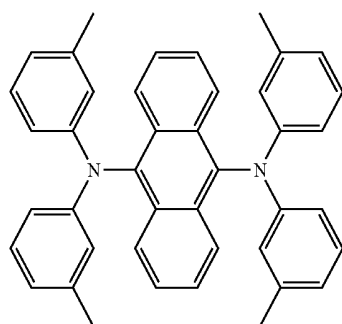
PD13



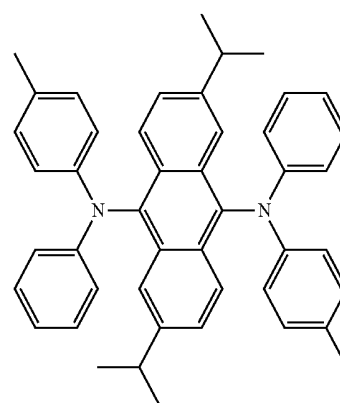
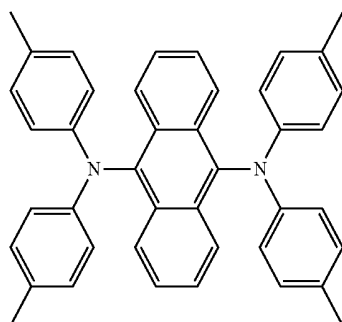
PD14



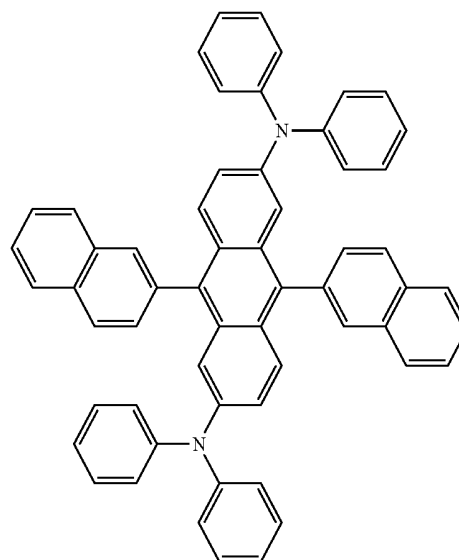
FD15



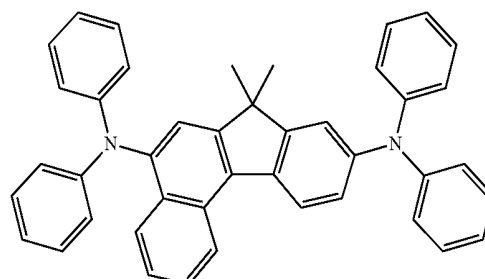
FD16



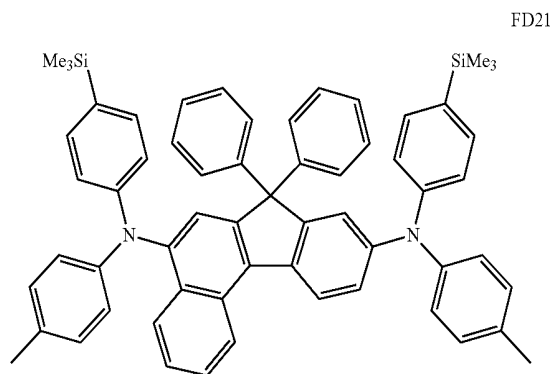
FD19



FD20

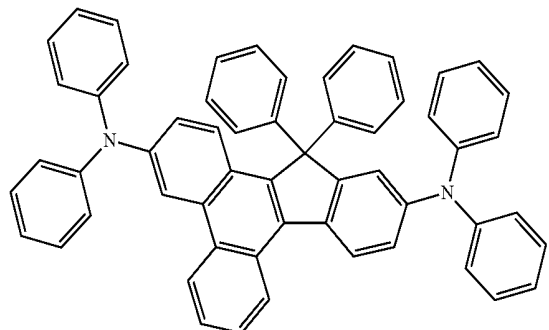


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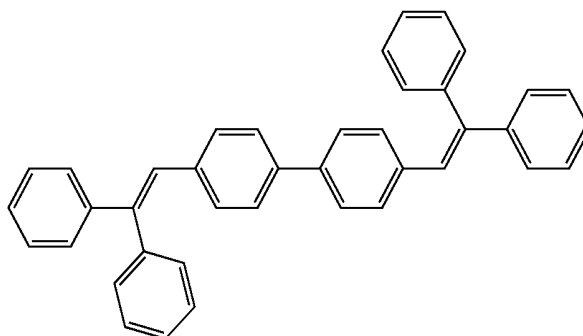


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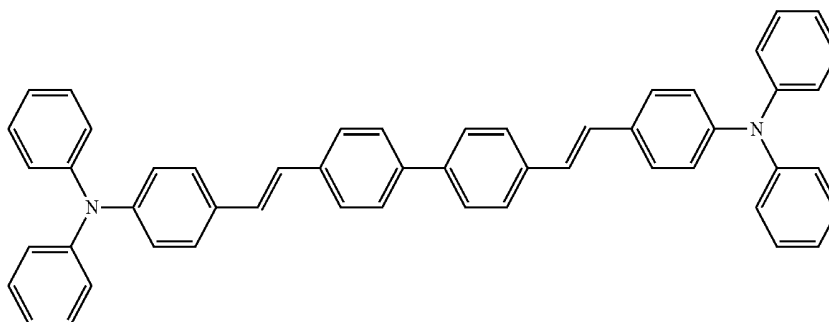
FD22



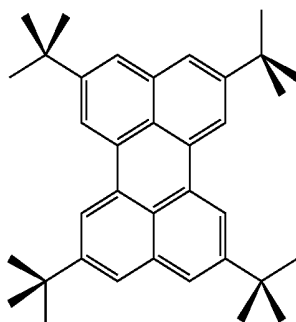
[0211] In one or more embodiments, the fluorescent dopant may be selected from the compounds illustrated below, but embodiments of the present disclosure are not limited thereto:



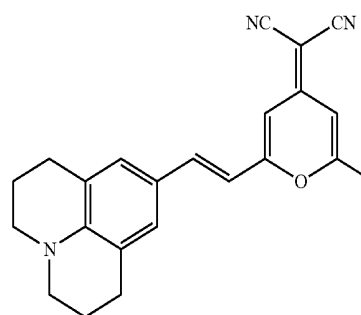
DPVBi



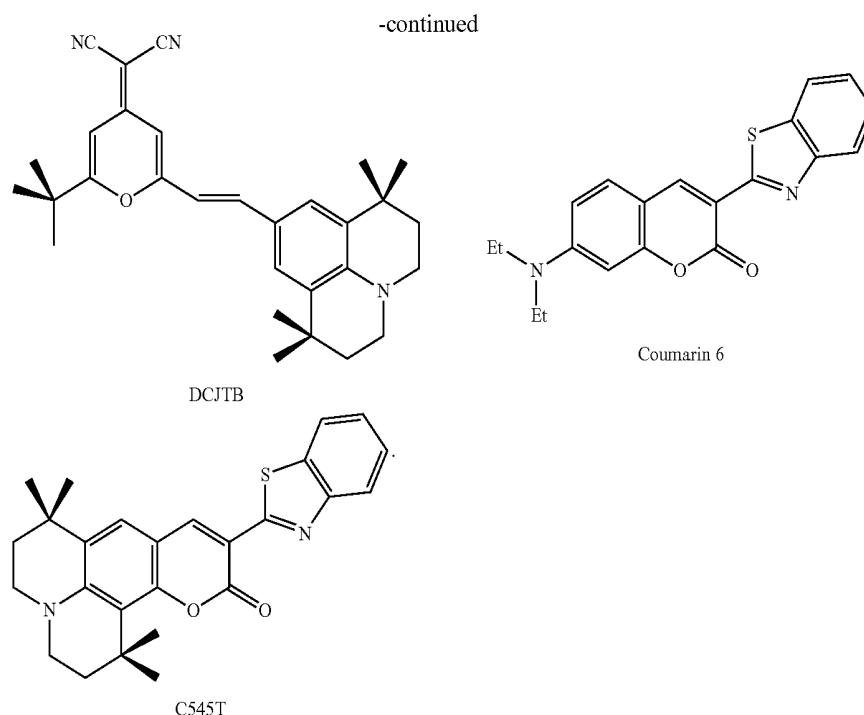
DPAVBi



TBPe



DCM



Electron Transport Region in Organic Layer 150

[0212] The electron transport region may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

[0213] The electron transport region may include at least one selected from a buffer layer, a hole blocking layer, an electron control layer, an electron transport layer (ETL), and an electron injection layer, but embodiments of the present disclosure are not limited thereto.

[0214] For example, the electron transport region may have a structure of electron transport layer/electron injection layer, a structure of hole blocking layer/electron transport layer/electron injection layer, a structure of electron control layer/electron transport layer/electron injection layer, or a structure of buffer layer/electron transport layer/electron injection layer, wherein layers of each structure are sequentially stacked on the emission layer in each stated order. However, embodiments of the structure of the electron transport layer are not limited thereto.

[0215] The electron transport region (for example, a buffer layer, a hole blocking layer, an electron control layer, and/or an electron transport layer in the electron transport region) may include a metal-free compound containing at least one π electron-depleted nitrogen-containing ring.

[0216] As used herein, “ π electron-depleted nitrogen-containing ring” indicates a C_1 - C_{60} heterocyclic group having at least one $*-N=*$ moiety as a ring-forming moiety.

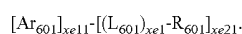
[0217] For example, the “ π electron-depleted nitrogen-containing ring” may be i) a 5-membered to 7-membered hetero monocyclic group having at least one $*-N=*$ moiety, ii) a heteropolycyclic group in which two or more 5-membered to 7-membered hetero monocyclic groups each having at least one $*-N=*$ moiety are condensed with

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

[0218] Non-limiting examples of the π electron-depleted nitrogen-containing ring may include an imidazole, a pyrazole, a thiazole, an isothiazole, an oxazole, an isoxazole, a pyridine, a pyrazine, a pyrimidine, a pyridazine, an indazole, a purine, a quinoline, an isoquinoline, a benzoquinoline, a phthalazine, a naphthyridine, a quinoxaline, a quinazoline, a cinnoline, a phenanthridine, an acridine, a phenanthroline, a phenazine, a benzimidazole, an isobenzothiazole, a benzoxazole, an isobenzoxazole, a triazole, a tetrazole, an oxadiazole, a triazine, a thiadiazole, an imidazopyridine, an imidazopyrimidine, and an azacarbazole, but embodiments of the present disclosure are not limited thereto.

[0219] The electron transport region may include the compound represented by Formula 1 according to an embodiment of the present disclosure. In one or more embodiments, the electron transport layer may include the compound represented by Formula 1 according to an embodiment of the present disclosure.

[0220] The electron transport region and/or the electron transport layer may further include, in addition to the compound of Formula 1, other known compounds. For example, the electron transport region may include a compound represented by Formula 601:



Formula 601

[0221] In Formula 601,

[0222] Ar_{601} may be selected from a substituted or unsubstituted C_5 - C_{60} carbocyclic group and a substituted and unsubstituted C_1 - C_{60} heterocyclic group,

[0223] $xe11$ may be selected from 1, 2, and 3,

[0224] L_{601} may be selected from a substituted or unsubstituted C_3 - C_{10} cycloalkylene group, a substituted or unsubstituted C_1 - C_{10} heterocycloalkylene group, a substituted or

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

[0225] xe1 may be an integer selected from 0 to 5,

[0226] R₆₀₁ may be selected from a substituted or unsubstituted C₃-C₁₀ cycloalkyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkyl group, a substituted or unsubstituted C₃-C₁₀ cycloalkenyl group, a substituted or unsubstituted C₁-C₁₀ heterocycloalkenyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₆-C₆₀ aryloxy group, a substituted or unsubstituted C₆-C₆₀ arylthio group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(Q₆₀₁)(Q₆₀₂)(Q₆₀₃), —C(=O)(Q₆₀₁), —S(=O)₂(Q₆₀₁), and —P(=O)(Q₆₀₁)(Q₆₀₂), wherein Q₆₀₁ to Q₆₀₃ may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, and

[0227] xe21 may be an integer selected from 1 to 5.

[0228] In one or more embodiments, at least one selected from the xe11 Ar₆₀₁(s) and the xe21 R₆₀₁(s) may include the π electron-depleted nitrogen-containing ring as described above.

[0229] In one or more embodiments, in Formula 601, ring Ar₆₀₁ may be selected from the group consisting of:

[0230] a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, a dibenzothiophene group, a carbazole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, a naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, a phenanthroline group, a phenazine group, a benzimidazole group, an isobenzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, thiadiazole group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group; and

[0231] a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, a dibenzothiophene group, a carbazole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a

pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, a naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, phenanthroline group, a phenazine group, a benzimidazole group, an isobenzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, thiadiazole group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, —Si(Q₃₁)(Q₃₂)(Q₃₃), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂),

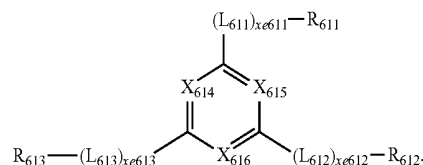
[0232] wherein Q₃₁ to Q₃₃ may each independently be selected from a C₁-C₁₀ alkyl group, a C₁-C₁₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0233] In Formula 601, when xe11 is two or more, two or more Ar₆₀₁(s) may be connected (e.g., coupled) via a single bond.

[0234] In one or more embodiments, in Formula 601, Ar₆₀₁ may be an anthracene group.

[0235] In one or more embodiments, the compound represented by Formula 601 may be represented by Formula 601-1:

Formula 601-1



[0236] In Formula 601-1,

[0237] X₆₁₄ may be selected from N and C(R₆₁₄), X₆₁₅ may be selected from N and C(R₆₁₅), and X₆₁₆ may be selected from N and C(R₆₁₆), wherein at least one selected from X₆₁₄ to X₆₁₆ may be N,

[0238] L₆₁₁ to L₆₁₃ may each independently be the same as described above in connection with L₆₀₁,

[0239] xe611 to xe613 may each independently be the same as described above in connection with xe1,

[0240] R₆₁₁ to R₆₁₃ may each independently be the same as described above in connection with R₆₀₁, and

[0241] R₆₁₄ to R₆₁₆ may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0242] In one or more embodiments, in Formulae 601 and 601-1, L₆₀₁ and L₆₁₁ to L₆₁₃ may each independently be selected from the group consisting of:

[0243] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthre-

nylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a thiophenylene group, a furanylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylenylene group, a benzothiophenylene group, a dibenzofuranylenylene group, a dibenzothiophenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, a pyridinylenylene group, an imidazolylenylene group, a pyrazolylenylene group, a thiazolylenylene group, an isothiazolylenylene group, an oxazolylenylene group, an isoxazolylenylene group, a thiadiazolylenylene group, an oxadiazolylenylene group, a pyrazinylenylene group, a pyrimidinylenylene group, a pyridazinylenylene group, a triazinylenylene group, a quinolinylenylene group, an isoquinolinylenylene group, a benzoquinolinylenylene group, a phthalazinylenylene group, a naphthyridinylenylene group, a quinoxalinylenylene group, a quinazolinylenylene group, a cinnolinylenylene group, a phenanthridinylenylene group, an acridinylenylene group, a phenanthrolinylenylene group, a phenazinylenylene group, a benzimidazolylenylene group, an isobenzothiazolylenylene group, a benzoxazolylenylene group, an isobenzoxazolylenylene group, a triazolylenylene group, a tetrazolylenylene group, an imidazopyridinylenylene group, an imidazopyrimidinylenylene group, and an azacarbazolylenylene group; and

[0244] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a thiophenylene group, a furanylene group, a carbazolylenylene group, an indolylenylene group, an isoindolylenylene group, a benzofuranylenylene group, a benzothiophenylene group, a dibenzofuranylenylene group, a dibenzothiophenylene group, a benzocarbazolylenylene group, a dibenzocarbazolylenylene group, a dibenzosilolylenylene group, a pyridinylenylene group, an imidazolylenylene group, a pyrazolylenylene group, a thiazolylenylene group, an isothiazolylenylene group, an oxazolylenylene group, an isoxazolylenylene group, a thiadiazolylenylene group, an oxadiazolylenylene group, a pyrazinylenylene group, a pyrimidinylenylene group, a pyridazinylenylene group, a triazinylenylene group, a quinolinylenylene group, an isoquinolinylenylene group, a benzoquinolinylenylene group, a phthalazinylenylene group, a naphthyridinylenylene group, a quinoxalinylenylene group, a quinazolinylenylene group, a cinnolinylenylene group, a phenanthridinylenylene group, an acridinylenylene group, a phenanthrolinylenylene group, a phenazinylenylene group, a benzimidazolylenylene group, an isobenzothiazolylenylene group, a benzoxazolylenylene group, an isobenzoxazolylenylene group, a triazolylenylene group, a tetrazolylenylene group, an imidazopyridinylenylene group, an imidazopyrimidinylenylene group, and an azacarbazolylenylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazoly group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzo-

thiophenyl group, a benzocarbazoly group, a dibenzocarbazoly group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinoliny group, an isoquinoliny group, a benzoquinoliny group, a phthalazinyl group, a naphthyridinyl group, a quinoxaliny group, a quinazoliny group, a cinnoliny group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, but embodiments of the present disclosure are not limited thereto.

[0245] In one or more embodiments, in Formulae 601 and 601-1, xe1 and xe611 to xe613 may each independently be selected from 0, 1, and 2.

[0246] In one or more embodiments, in Formulae 601 and 601-1, R_{601} and R_{611} to R_{613} may each independently be selected from the group consisting of:

[0247] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazoly group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazoly group, a dibenzocarbazoly group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinoliny group, an isoquinoliny group, a benzoquinoliny group, a phthalazinyl group, a naphthyridinyl group, a quinoxaliny group, a quinazoliny group, a cinnoliny group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group;

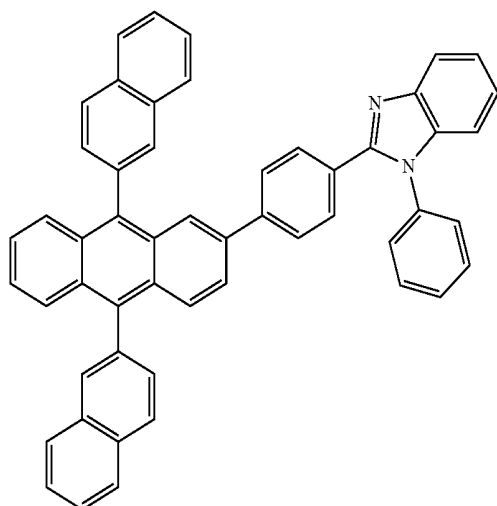
[0248] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazoly group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazoly group, a dibenzocarbazoly group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinoliny group, an isoquinoliny group, a benzoquinoliny group, a phthalazinyl group, a naphthyridinyl group, a quinoxaliny group, a quinazoliny group, a cinnoliny group, a phenanthridinyl group, an acridinyl group, a

phenanthrolyl group, a phenaziny group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolyl group, a phenaziny group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group; and

—S(=O)₂(Q₆₀₁) and —P(=O)(Q₆₀₁)(Q₆₀₂),

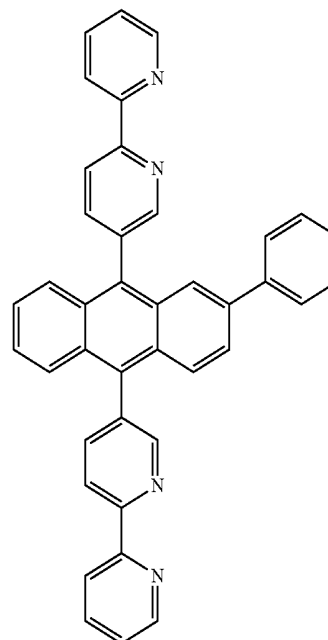
[0249] wherein Q₆₀₁ and Q₆₀₂ may each independently be the same as described above.

[0250] The electron transport region may include at least one selected from Compounds ET1 to ET36, but embodiments of the present disclosure are not limited thereto:

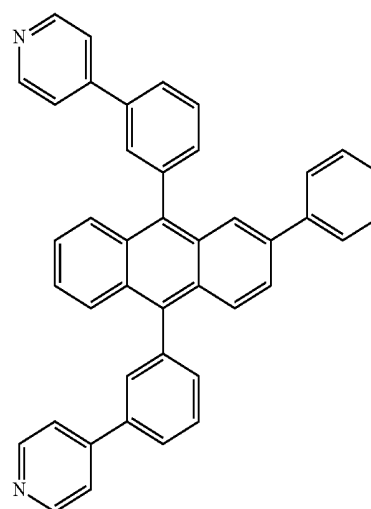


ET1

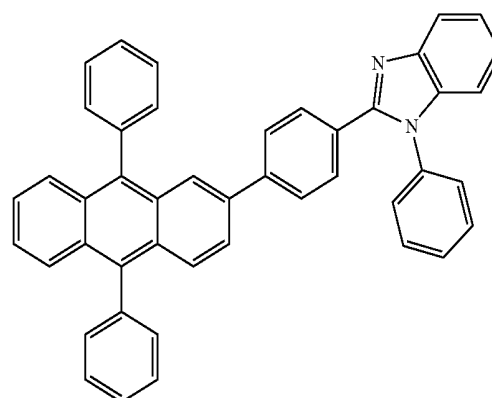
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ET2

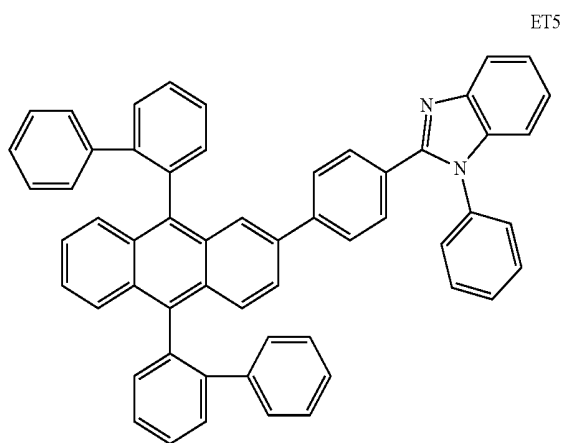


ET3

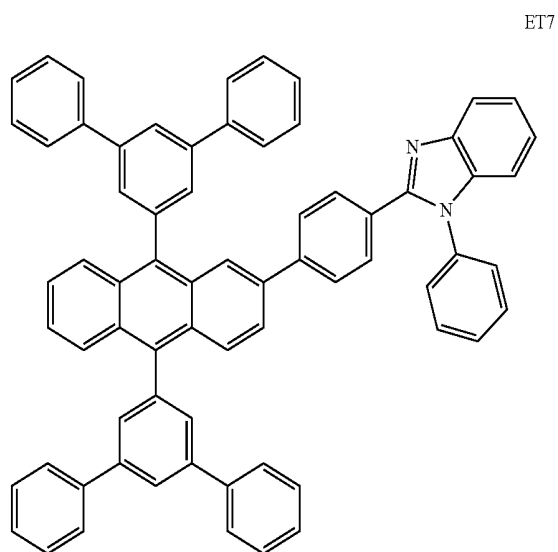
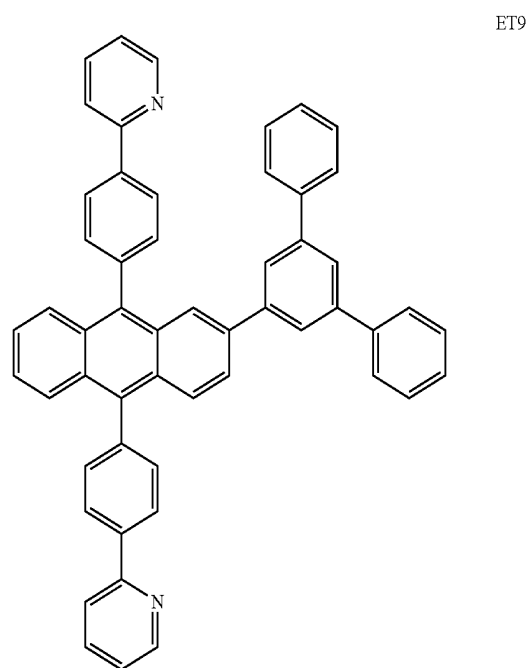
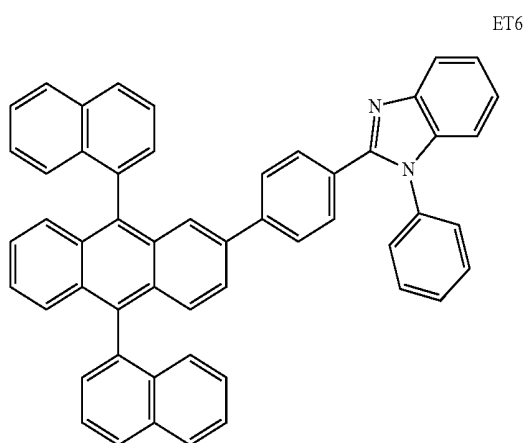
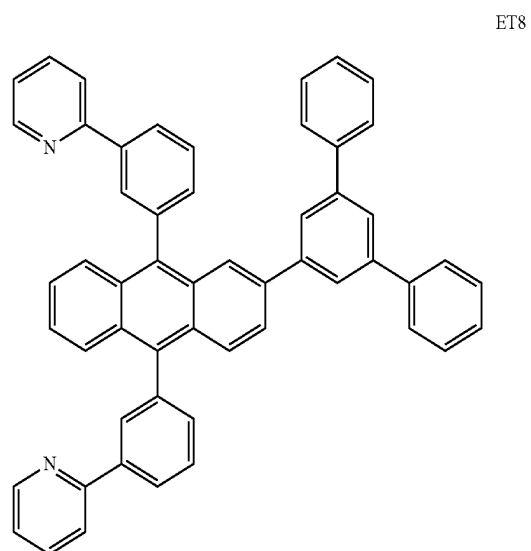


ET4

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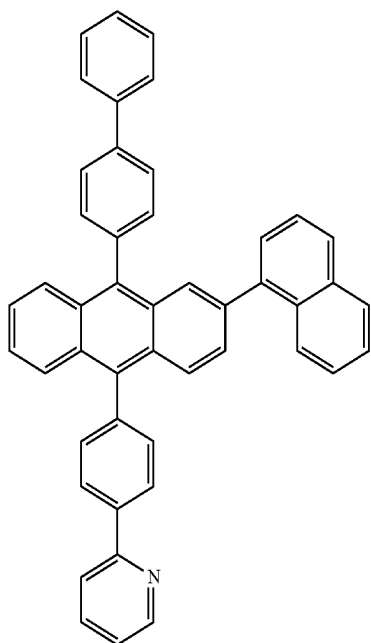


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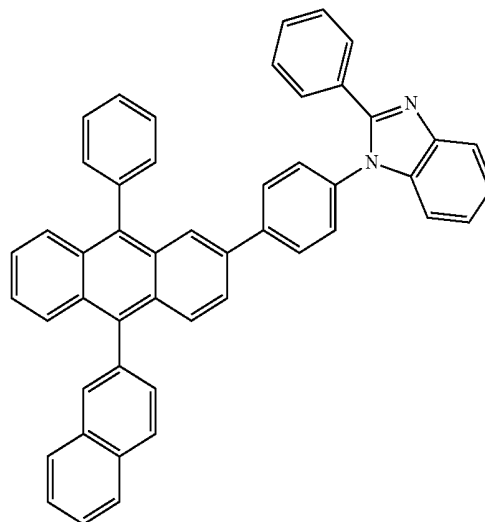
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ET10

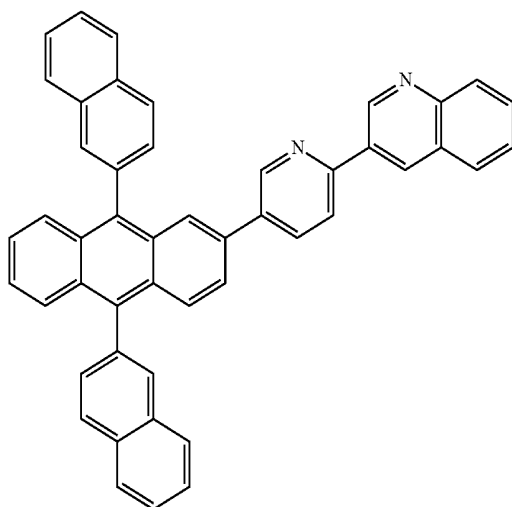


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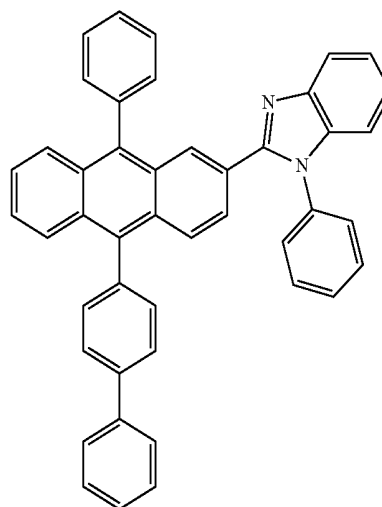
ET13



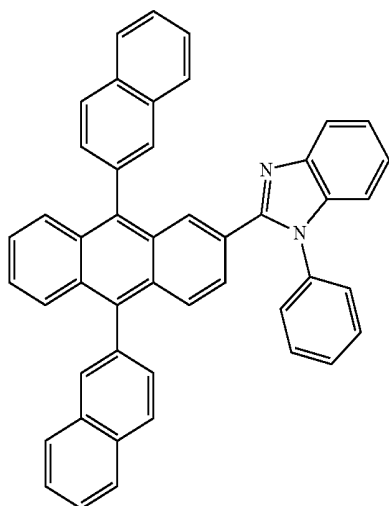
ET11



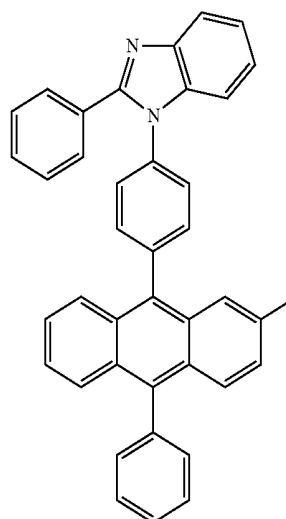
ET14



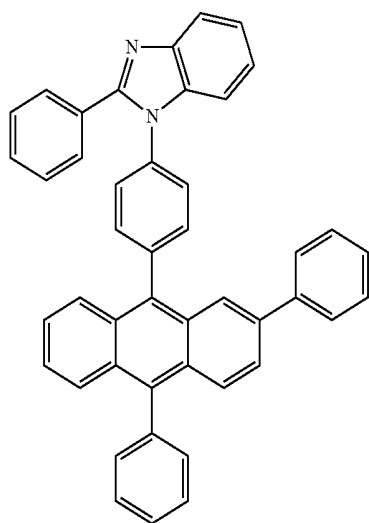
ET12



ET15



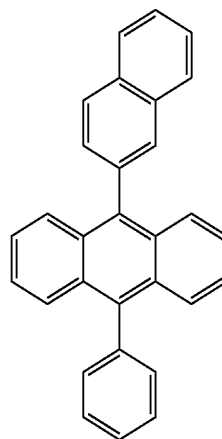
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ET16

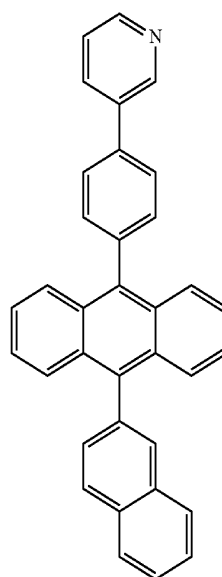
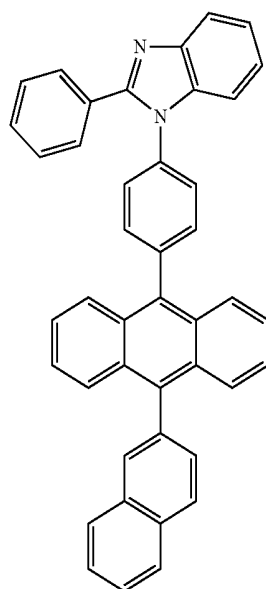
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ET19



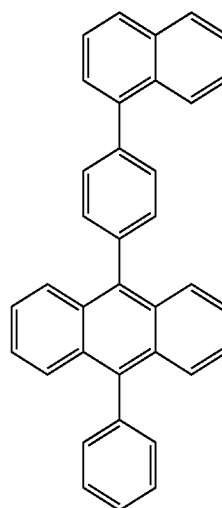
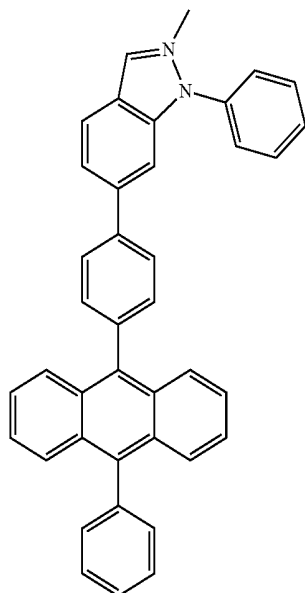
ET17

ET20



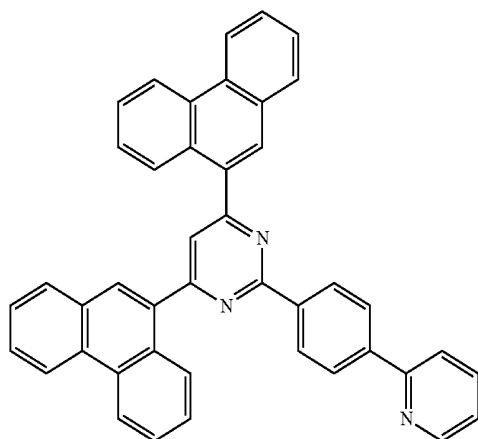
ET18

ET21



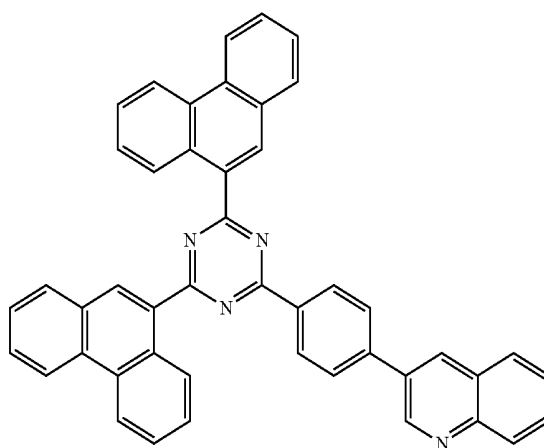
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ET22

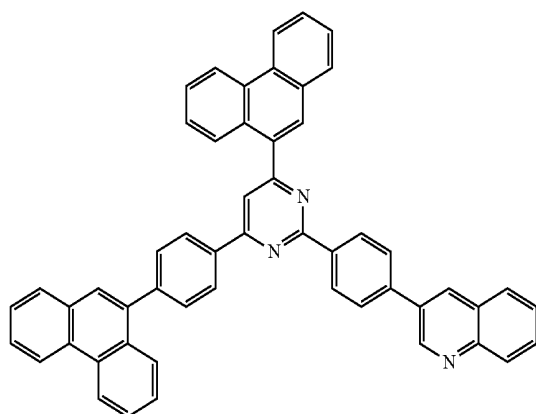


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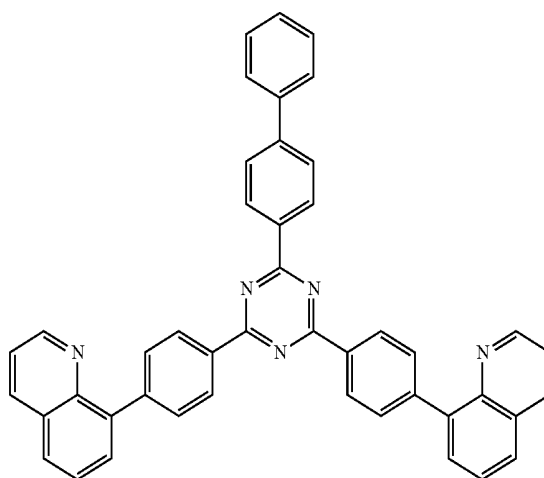
ET25



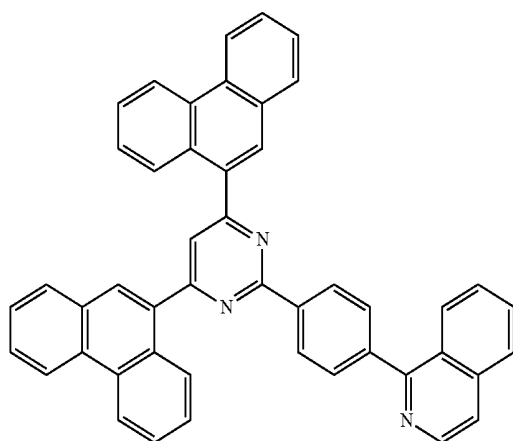
ET23



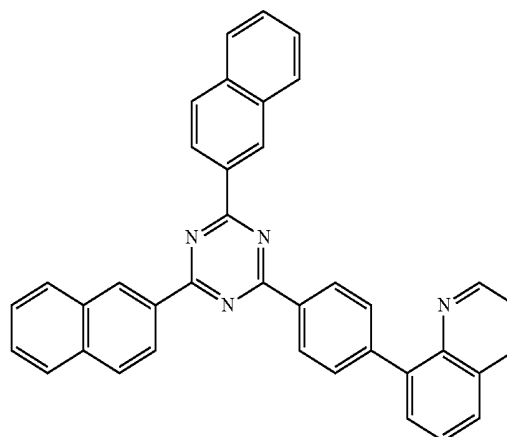
ET26



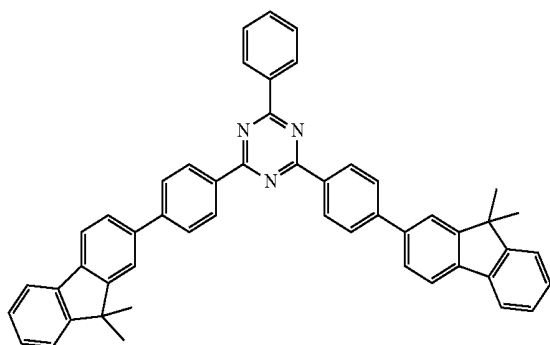
ET24



ET27

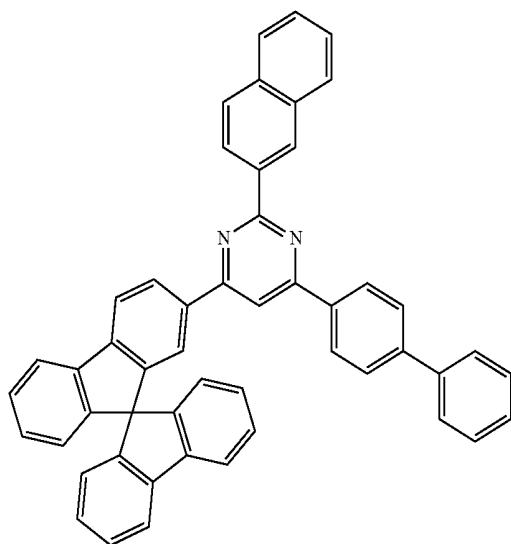


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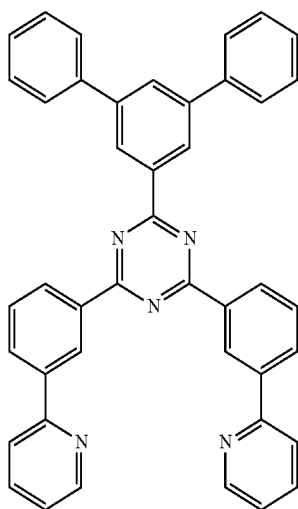


ET28

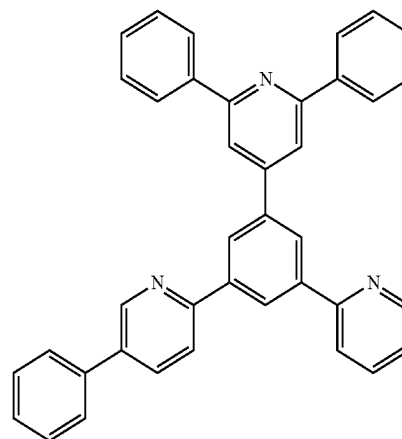
ET29



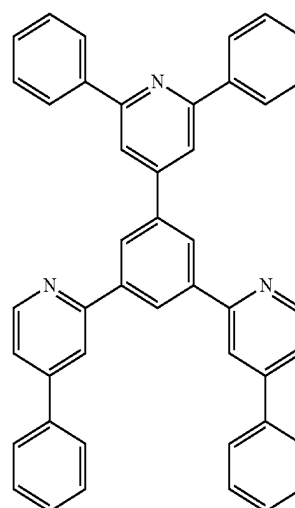
ET30



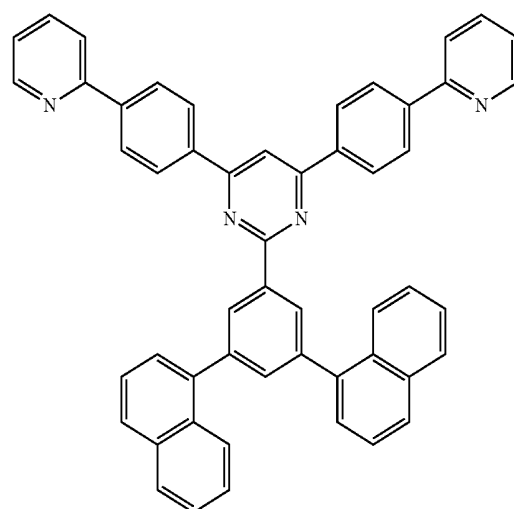
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ET31

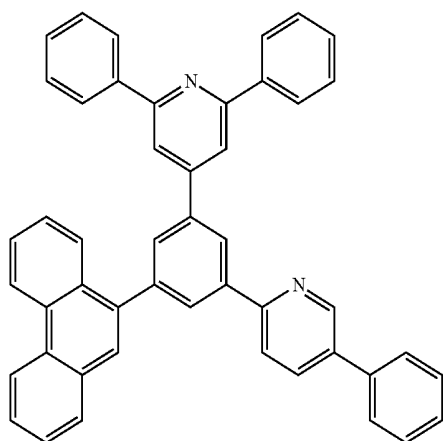


ET32

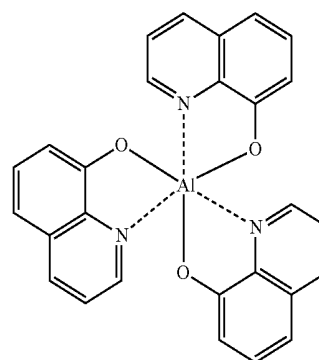
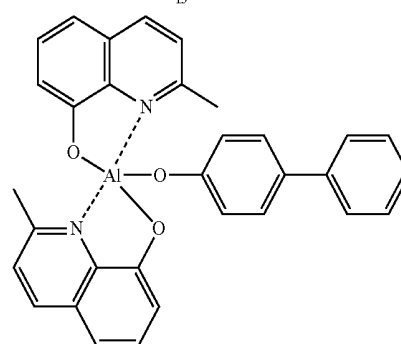


ET33

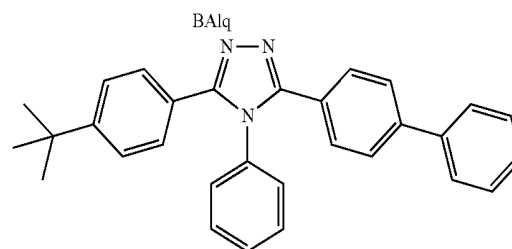
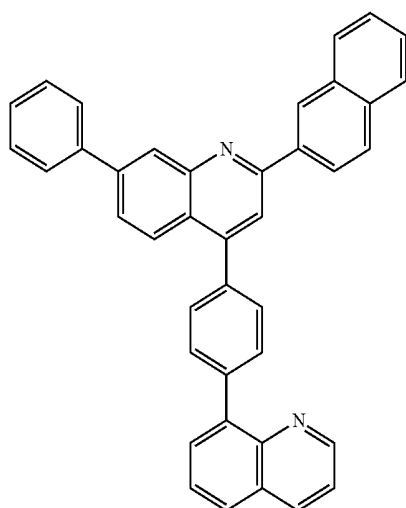
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ET34

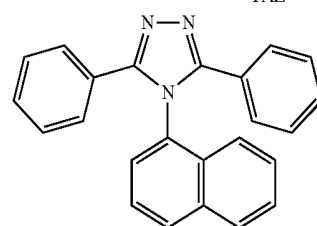
Alq₃

ET35



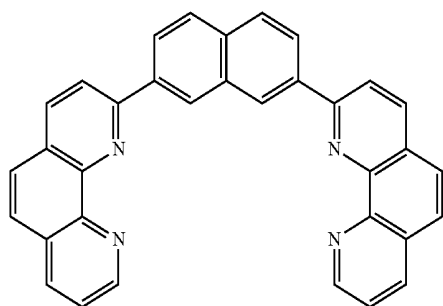
BALq

TAZ



NTAZ

ET36



[0251] In one or more embodiments, the electron transport region may include at least one compound selected from 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP), 4,7-diphenyl-1,10-phenanthroline (Bphen), Alq₃, Balq, 3-(biphenyl-4-yl)-5-(4-tert-butylphenyl)-4-phenyl-4H-1,2,4-triazole (TAZ), and NTAZ:

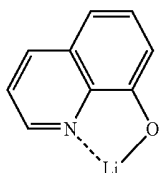
[0252] The thicknesses of the buffer layer, the hole blocking layer, and/or the electron control layer may be about 20 Å to about 1,000 Å, and in some embodiments, about 30 Å to about 300 Å. When the thicknesses of the buffer layer, the hole blocking layer, and the electron control layer are each within these ranges, the electron blocking layer may have excellent electron blocking characteristics and/or electron control characteristics without a substantial increase in driving voltage.

[0253] The thickness of the electron transport layer may be about 100 Å to about 1,000 Å, and in some embodiments, about 150 Å to about 500 Å. When the thickness of the electron transport layer is within these ranges, the electron transport layer may have satisfactory electron transport characteristics without a substantial increase in driving voltage.

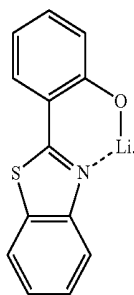
[0254] The electron transport region (for example, the electron transport layer in the electron transport region) may further include, in addition to the materials described above, a metal-containing material.

[0255] The metal-containing material may include at least one selected from an alkali metal complex and an alkaline earth metal complex. The alkali metal complex may include a metal ion selected from a lithium (Li) ion, a sodium (Na) ion, a potassium (K) ion, a rubidium (Rb) ion, and a cesium (Cs) ion, and the alkaline earth metal complex may include a metal ion selected from a beryllium (Be) ion, a magnesium (Mg) ion, a calcium (Ca) ion, a strontium (Sr) ion, and a barium (Ba) ion. One or more ligands coordinated with the metal ion of the alkali metal complex and/or the alkaline earth metal complex may be selected from a hydroxyquinoline, a hydroxyisoquinoline, a hydroxybenzoquinoline, a hydroxyacridine, a hydroxyphenanthridine, a hydroxyphenyl oxazole, a hydroxyphenyl thiazole, a hydroxydiphenyl oxadiazole, a hydroxydiphenyl thiadiazole, a hydroxyphenyl pyridine, a hydroxyphenyl benzimidazole, a hydroxyphenyl benzothiazole, a bipyridine, a phenanthroline, and a cyclopentadiene, but embodiments of the present disclosure are not limited thereto.

[0256] For example, the metal-containing material may include a Li complex. The Li complex may include, for example, Compound ET-D1 (lithium quinolate, LiQ) and/or Compound ET-D2:



ET-D1



ET-D2

[0257] The electron transport region may include an electron injection layer that facilitates injection of electrons from the second electrode **190**. The electron injection layer may directly contact the second electrode **190**.

[0258] The electron injection layer may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

[0259] The electron injection layer may include a reducing dopant.

[0260] The reducing dopant may include at least one selected from an alkali metal, an alkaline earth metal, a rare earth based metal, an alkali metal compound, an alkaline earth metal compound, a rare earth based metal compound,

an alkali metal complex, an alkaline earth metal complex, and a rare earth based metal complex.

[0261] The alkali metal may be selected from Na, K, Rb, and Cs. In one or more embodiments, the alkali metal may be selected from K, Rb, and Cs. In one or more embodiments, the alkali metal may be selected from Rb and Cs, but embodiments of the present disclosure are not limited thereto.

[0262] The alkaline earth metal may be selected from Ca, Sr, and Ba.

[0263] The rare earth metal may be selected from scandium (Sc), yttrium (Y), cerium (Ce), ytterbium (Yb), gadolinium (Gd), and terbium (Tb).

[0264] The alkali metal compound, the alkaline earth metal compound, and the rare earth metal compound may be selected from oxides and halides (for example, fluorides, chlorides, bromides, and/or iodides) of the alkali metal, the alkaline earth metal, and the rare earth metal.

[0265] The alkali metal compound may be selected from alkali metal oxides (such as Li_2O , Cs_2O , and/or K_2O) and alkali metal halides (such as LiF, NaF, CsF, KF, LiI, NaI, CsI, and/or KI). In one or more embodiments, the alkali metal compound may be selected from LiF, Li_2O , NaF, LiI, NaI, CsI, and KI, but embodiments of the present disclosure are not limited thereto.

[0266] The alkaline earth metal compound may be selected from alkaline earth metal compounds (such as BaO, SrO, CaO, $\text{Ba}_x\text{Sr}_{1-x}\text{O}$ ($0 < x < 1$), and/or $\text{Ba}_x\text{Ca}_{1-x}\text{O}$ ($0 < x < 1$)). In one or more embodiments, the alkaline earth metal compound may be selected from BaO, SrO, and CaO, but embodiments of the present disclosure are not limited thereto.

[0267] The rare earth metal compound may be selected from YbF_3 , ScF_3 , ScO_3 , Y_2O_3 , Ce_2O_3 , GdF_3 , and TbF_3 . In one or more embodiments, the rare earth metal compound may be selected from YbF_3 , ScF_3 , TbF_3 , YbI_3 , ScI_3 , and TbI_3 , but embodiments of the present disclosure are not limited thereto.

[0268] The alkali metal complex, the alkaline earth metal complex, and the rare earth metal complex may each include a metal ion selected from an alkali metal, an alkaline earth metal, and a rare earth metal as described above, respectively. Each ligand coordinated with a metal ion in the alkali metal complex, the alkaline earth metal complex, and/or the rare earth metal complex may independently be selected from a hydroxyquinoline, a hydroxyisoquinoline, a hydroxybenzoquinoline, a hydroxyacridine, a hydroxyphenanthridine, a hydroxyphenyl oxazole, a hydroxyphenyl thiazole, a hydroxydiphenyl oxadiazole, a hydroxydiphenyl thiadiazole, a hydroxyphenyl pyridine, a hydroxyphenyl benzimidazole, a hydroxyphenyl benzothiazole, a bipyridine, a phenanthroline, and a cyclopentadiene, but embodiments of the present disclosure are not limited thereto.

[0269] The electron injection layer may include only the reducing dopant as described above. In one or more embodiments, the electron injection layer may further include, in addition to the reducing dopant, an organic material. When the electron injection layer includes the reducing dopant and an organic material, the reducing dopant may be homogeneously or non-homogeneously dispersed in a matrix including the organic material.

[0270] 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 these ranges, the electron injection layer may have satisfactory electron injection characteristics without a substantial increase in driving voltage.

Second Electrode 190

[0271] The second electrode 190 may be on the organic layer 150. The second electrode 190 may be a cathode, which is an electron injection electrode, and in this regard, a material for forming the second electrode 190 may be selected from a metal, an alloy, an electrically conductive compound, and a mixture thereof, each having a relatively low work function.

[0272] The second electrode 190 may include at least one selected from Li, Mg, Al, Al—Li, Ca, Mg—In, Mg—Ag, ITO, and IZO, but embodiments of the present disclosure are not limited thereto. The second electrode 190 may be a transmissive electrode, a semi-transmissive electrode, or a reflective electrode.

[0273] The second electrode 190 may have a single-layered structure, or a multi-layered structure including two or more layers.

[0274] According to an embodiment of the present disclosure, the organic light-emitting device may be suitably included in one or more types or kinds of display apparatuses, for example, a passive matrix organic light-emitting display apparatus and an active matrix organic light-emitting display apparatus. For example, when the organic light-emitting device is included in an active matrix organic light-emitting display apparatus, a first electrode on a substrate may be a pixel electrode, and the first electrode may be electrically connected to a source electrode or a drain electrode of a thin film transistor 200. In some embodiments, the organic light-emitting device may be included in a display apparatus that may display images on both sides.

Description of FIGS. 2 to 4

[0275] The organic light-emitting device 20 of FIG. 2 may include a first capping layer 210, a first electrode 110, an organic layer 150, and a second electrode 190, which are sequentially stacked in this stated order. The organic light-emitting device 30 of FIG. 3 may include a first electrode 110, an organic layer 150, a second electrode 190, and a second capping layer 220, which are sequentially stacked in this stated order. The organic light-emitting device 40 of FIG. 4 includes a first capping layer 210, a first electrode 110, an organic layer 150, a second electrode 190, and a second capping layer 220, which are sequentially stacked in this stated order.

[0276] In FIGS. 2 to 4, the first electrode 110, the organic layer 150, and the second electrode 190 may each be the same as described herein in connection with FIG. 1.

[0277] In the organic layer 150 of each of the organic light-emitting devices 20 and 40, light generated in an emission layer may pass through the first electrode 110 (which is a semi-transmissive electrode or a transmissive electrode) and the first capping layer 210 toward the outside, and in the organic layer 150 of each of the organic light-emitting devices 30 and 40, light generated in an emission layer may pass through the second electrode 190 (which is a semi-transmissive electrode or a transmissive electrode) and the second capping layer 220 toward the outside.

[0278] The first capping layer 210 and the second capping layer 220 may increase the external luminescent efficiency of the organic light emitting device according to the principle of constructive interference. 4

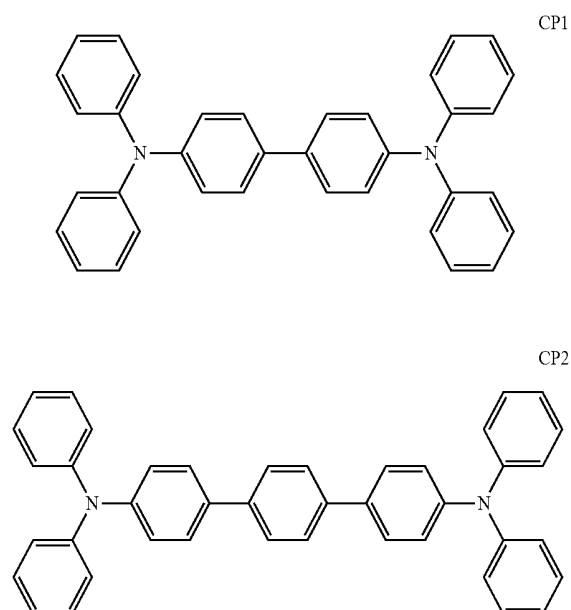
[0279] The first capping layer 210 and the second capping layer 220 may each independently be an organic capping layer including an organic material, an inorganic capping layer including an inorganic material, or a composite capping layer including an organic material and an inorganic material.

[0280] At least one selected from the first capping layer 210 and the second capping layer 220 may include at least one material selected from carbocyclic compounds, heterocyclic compounds, amine-based compounds, porphyrin derivatives, phthalocyanine derivatives, naphthalocyanine derivatives, alkali metal complexes, and alkaline earth metal complexes. The carbocyclic compound, the heterocyclic compound, and the amine-based compound may be optionally substituted with a substituent containing at least one element selected from O, N, sulfur (S), selenium (Se), silicon (Si), fluorine (F), chlorine (Cl), bromine (Br), and iodine (I).

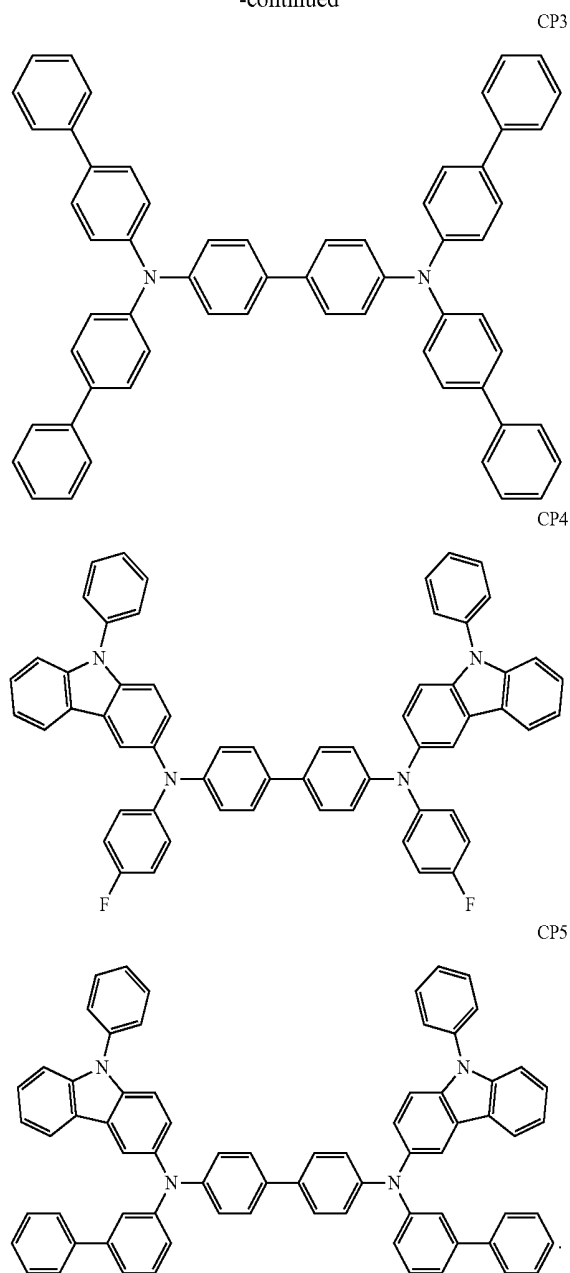
[0281] In one or more embodiments, at least one selected from the first capping layer 210 and the second capping layer 220 may include an amine-based compound.

[0282] In one or more embodiments, at least one selected from the first capping layer 210 and the second capping layer 220 may include the compound represented by Formula 201 or the compound represented by Formula 202.

[0283] In one or more embodiments, at least one selected from the first capping layer 210 and the second capping layer 220 may include a compound selected from Compounds HT28 to HT33 and Compounds CP1 to CP5, but embodiments of the present disclosure are not limited thereto:



-continued



[0284] Hereinbefore, the organic light-emitting device according to an embodiment of the present disclosure has been described in connection with FIGS. 1 to 4. However, embodiments of the present disclosure are not limited thereto.

[0285] The layers constituting the hole transport region, the emission layer, and the layers constituting the electron transport region may be formed in a specific region using one or more methods selected from vacuum deposition, spin coating, casting, a Langmuir-Blodgett (LB) method, ink-jet printing, laser-printing, and laser-induced thermal imaging (LITI).

[0286] When the layers constituting the hole transport region, the emission layer, and the layers constituting the electron transport region are each formed by vacuum deposition, 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 included in each layer, and the intended structure of each layer to be formed.

[0287] When the layers constituting the hole transport region, the emission layer, and the layers constituting the electron transport region are formed by spin coating, the spin coating may be performed at a coating speed of about 2,000 rpm to about 5,000 rpm and at a heat treatment temperature of about 80° C. to 200° C., depending on the compound to be included in each layer, and the intended structure of each layer to be formed.

General Definition of Substituents

[0288] Hereinafter, definitions of representative substituents of compounds used herein will be presented. The number of carbon atoms used to restrict a substituent is not limited, and does not limit the properties of the substituent. Unless defined otherwise, the definition of the substituent is consistent with a general definition thereof.

[0289] The term “ C_1 - C_{60} alkyl group” as used herein refers to a linear or branched aliphatic hydrocarbon monovalent group having 1 to 60 carbon atoms, and non-limiting examples thereof may include a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, a pentyl group, an iso-amyl group, and a hexyl group. The term “ C_1 - C_{60} alkylene group” as used herein refers to a divalent group having substantially the same structure as the C_1 - C_{60} alkyl group.

[0290] The term “ C_2 - C_{60} alkenyl group” as used herein refers to a hydrocarbon group having at least one carbon-carbon double bond in the body (e.g., middle) or at the terminus of the C_2 - C_{60} alkyl group, and non-limiting examples thereof may include an ethenyl group, a propenyl group, and a butenyl group. The term “ C_2 - C_{60} alkenylene group” as used herein refers to a divalent group having substantially the same structure as the C_2 - C_{60} alkenyl group.

[0291] The term “ C_2 - C_{60} alkynyl group” as used herein refers to a hydrocarbon group having at least one carbon-carbon triple bond in the body (e.g., middle) or at the terminus of the C_2 - C_{60} alkyl group, and non-limiting examples thereof may include an ethynyl group and a propynyl group. The term “ C_2 - C_{60} alkynylene group” as used herein refers to a divalent group having substantially the same structure as the C_2 - C_{60} alkynyl group.

[0292] The term “ C_1 - C_{60} alkoxy group” as used herein refers to a monovalent group represented by $-O-A_{101}$ (wherein A_{101} is a C_1 - C_{60} alkyl group), and non-limiting examples thereof may include a methoxy group, an ethoxy group, and an isopropoxy group.

[0293] The term “ C_3 - C_{10} cycloalkyl group” as used herein refers to a monovalent hydrocarbon monocyclic group having 3 to 10 carbon atoms, and non-limiting examples thereof may include a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. The term “ C_3 - C_{10} cycloalkylene group” as used herein refers to a divalent group having substantially the same structure as the C_3 - C_{10} cycloalkyl group.

[0294] The term “ C_1 - C_{10} heterocycloalkyl group” as used herein refers to a monovalent monocyclic group having at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom in addition 1 to 10 carbon atoms. Non-limiting examples thereof may include a 1,2,3,4-oxatriazolidinyl group, a tetrahydrofuranlyl group, and a tetrahydro-

thiophenyl group. The term “C₁-C₁₀ heterocycloalkylene group” as used herein refers to a divalent group having substantially the same structure as the C₁-C₁₀ heterocycloalkyl group.

[0295] The term “C₃-C₁₀ cycloalkenyl group” as used herein refers to a monovalent monocyclic group that has 3 to 10 carbon atoms and at least one double bond in the ring thereof, and does not have aromaticity (e.g., is non-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 refers to a divalent group having substantially the same structure as the C₃-C₁₀ cycloalkenyl group.

[0296] The term “C₁-C₁₀ heterocycloalkenyl group” as used herein refers to a monovalent monocyclic group that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, 1 to 10 carbon atoms, and at least one double bond in its ring. Non-limiting examples of the C₁-C₁₀ heterocycloalkenyl group may include a 4,5-dihydro-1,2,3,4-oxatriazolyl group, a 2,3-hydrofuranlyl group, and a 2,3-hydrothiophenyl group. The term “C₁-C₁₀ heterocycloalkenylene group” as used herein refers to a divalent group having substantially the same structure as the C₁-C₁₀ heterocycloalkenyl group.

[0297] The term “C₆-C₆₀ aryl group” as used herein refers to a monovalent group having a carbocyclic aromatic system including 6 to 60 carbon atoms, and the term “C₆-C₆₀ arylene group” as used herein refers to a divalent group having a carbocyclic aromatic system including 6 to 60 carbon atoms. Non-limiting examples of the C₆-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 C₆-C₆₀ aryl group and the C₆-C₆₀ arylene group each include two or more rings, the rings may be fused (e.g., condensed).

[0298] The term “C₁-C₆₀ heteroaryl group” as used herein refers to a monovalent group having a carbocyclic aromatic system that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom in addition to 1 to 60 carbon atoms. The term “C₁-C₆₀ heteroarylene group” as used herein refers to a divalent group having a carbocyclic aromatic system that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, in addition to 1 to 60 carbon atoms. Non-limiting examples of the C₁-C₆₀ heteroaryl group 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 two or more rings, the rings may be fused (e.g., condensed).

[0299] The term “C₆-C₆₀ aryloxy group” as used herein indicates —O-A₁₀₂ (wherein A₁₀₂ is a C₆-C₆₀ aryl group), and the term “C₆-C₆₀ arylthio group” as used herein indicates —S-A₁₀₃ (wherein A₁₀₃ is a C₆-C₆₀ aryl group).

[0300] The term “monovalent non-aromatic condensed polycyclic group” as used herein refers to a monovalent group that has two or more rings condensed with each other, only carbon atoms (for example, 8 to 60 carbon atoms) as ring-forming atoms, and non-aromaticity in the entire molecular structure (e.g., the molecule as a whole is non-aromatic). A non-limiting example of the monovalent non-aromatic condensed polycyclic group may include a fluorenyl group. The term “divalent non-aromatic condensed polycyclic group” as used herein refers to a divalent group

having substantially the same structure as the monovalent non-aromatic condensed polycyclic group.

[0301] The term “monovalent non-aromatic condensed heteropolycyclic group” as used herein refers to a monovalent group that has two or more rings condensed, has at least one heteroatom selected from N, O, Si, P, and S in addition to carbon atoms (for example, 1 to 60 carbon atoms) as ring-forming atoms, and has non-aromaticity in the entire molecular structure. A non-limiting example of the monovalent non-aromatic condensed heteropolycyclic group may include a carbazolyl group. The term “divalent non-aromatic condensed heteropolycyclic group” as used herein refers to a divalent group having substantially the same structure as the monovalent non-aromatic condensed heteropolycyclic group.

[0302] The term “C₅-C₆₀ carbocyclic group” as used herein refers to a monocyclic or polycyclic group having 5 to 60 carbon atoms in which the ring-forming atoms are all carbons. The C₅-C₆₀ carbocyclic group may be an aromatic carbocyclic group or a non-aromatic carbocyclic group. The C₅-C₆₀ carbocyclic group may be a ring (such as benzene), a monovalent group (such as a phenyl group), or a divalent group (such as a phenylene group). In one or more embodiments, depending on the number of substituents connected (e.g., coupled) to the C₅-C₆₀ carbocyclic group, the C₅-C₆₀ carbocyclic group may be a trivalent group or a quadrivalent group.

[0303] The term “C₁-C₆₀ heterocyclic group” as used herein refers to a group having substantially the same structure as the C₅-C₆₀ carbocyclic group, except that at least one heteroatom selected from N, O, Si, P, and S is used in addition to the carbon atoms as a ring-forming atom. The number of carbon atoms may be 1 to 60.

[0304] At least one substituent of the substituted C₅-C₆₀ carbocyclic group, the substituted C₁-C₆₀ heterocyclic group, the substituted C₃-C₁₀ cycloalkylene group, the substituted C₁-C₁₀ heterocycloalkylene group, the substituted C₃-C₁₀ cycloalkenylene group, the substituted C₁-C₁₀ heterocycloalkenylene group, the substituted C₆-C₆₀ arylene group, the substituted C₁-C₆₀ heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, the substituted divalent non-aromatic condensed heteropolycyclic group, the substituted C₁-C₆₀ alkyl group, the substituted C₂-C₆₀ alkenyl group, the substituted C₂-C₆₀ alkynyl group, the substituted C₁-C₆₀ alkoxy group, the substituted C₃-C₁₀ cycloalkyl group, the substituted C₁-C₁₀ heterocycloalkyl group, the substituted C₃-C₁₀ cycloalkenyl group, the substituted C₁-C₁₀ heterocycloalkenyl group, the substituted C₆-C₆₀ aryl group, the substituted C₆-C₆₀ aryloxy group, the substituted C₆-C₆₀ arylthio group, the substituted C₁-C₆₀ heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from the group consisting of:

[0305] deuterium(-D), —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group;

[0306] a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono

group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —Si(Q₁₁)(Q₁₂)(Q₁₃), —N(Q₁₁)(Q₁₂), —B(Q₁₁)(Q₁₂), —C(=O)(Q₁₁), —S(=O)₂(Q₁₁), and —P(=O)(Q₁₁)(Q₁₂);

[0307] 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;

[0308] a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —Si(Q₂₁)(Q₂₂)(Q₂₃), —N(Q₂₁)(Q₂₂), —B(Q₂₁)(Q₂₂), —C(=O)(Q₂₁), —S(=O)₂(Q₂₁), and —P(=O)(Q₂₁)(Q₂₂); and

[0309] —Si(Q₃₁)(Q₃₂)(Q₃₃), —N(Q₃₁)(Q₃₂), —B(Q₃₁)(Q₃₂), —C(=O)(Q₃₁), —S(=O)₂(Q₃₁), and —P(=O)(Q₃₁)(Q₃₂),

[0310] wherein Q₁₁ to Q₁₃, Q₂₁ to Q₂₃, and Q₃₁ to Q₃₃ may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₁-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₁-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group and a terphenyl group.

[0311] The term “Ph” as used herein refers to a phenyl group, the term “Me” as used herein refers to a methyl group, the term “Et” as used herein refers to an ethyl group, the term “ter-Bu” or “Bu” as used herein refers to a tert-butyl group, and the term “OMe” as used herein refers to a methoxy group.

[0312] The term “biphenyl group” as used herein refers to “a phenyl group substituted with a phenyl group”. In other words, a “biphenyl group” refers to “a substituted phenyl group having a C₆-C₆₀ aryl group as a substituent”.

[0313] The term “terphenyl group” as used herein refers to “a phenyl group substituted with a biphenyl group”. In other

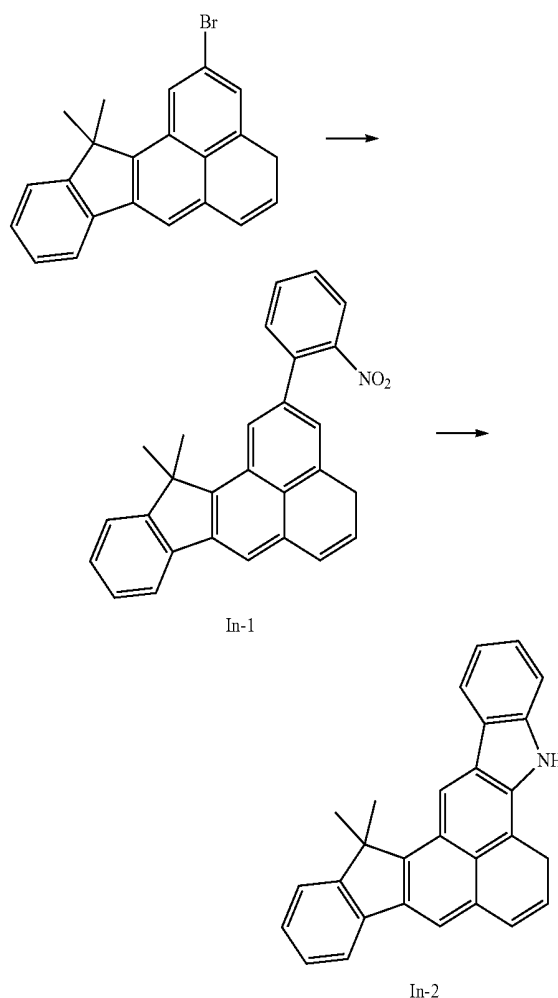
words, a “terphenyl group” refers to “a substituted phenyl group having a C₆-C₆₀ aryl group substituted with a C₆-C₆₀ aryl group as a substituent”.

[0314] Symbols * and *[†] as used herein, unless defined otherwise, refer to binding sites to neighboring atoms in a corresponding formula.

[0315] Hereinafter, a compound represented by Formula 1 according to an embodiment of the present disclosure and an organic light-emitting device according to an embodiment of the present disclosure will be described in more detail with reference to Synthesis Examples and Examples. The wording “B was used instead of A” used in describing Synthesis Examples refers to that an identical number of molar equivalents of A was used in place of B.

SYNTHESIS EXAMPLES

[0316]



Synthesis Example 1: Synthesis of Intermediate-2 (In-2)

Synthesis of Intermediate-1 (In-1)

[0317] Pd(PPh₃)₄ (0.02 equivalent (eq)), Na₂CO₃ (1.2 eq), and a mixture of toluene, distilled water, and ethanol (5:3:2 (v/v) based on 0.1 M reagent (1 eq)) were added to a flask

containing 2-bromo-12,12-dimethyl-4,12-dihydroindeno[2,1-a]phenalene (1 eq) and (2-nitrophenyl)boronic acid (1.2 eq), and the mixed solution was stirred under reflux for 12 hours. The reaction solution was cooled to room temperature, and extraction was performed using methylene chloride (MC), followed by washing using distilled water. The resulting solution was dried with MgSO_4 , filtered, and distilled under reduced pressure. The residue obtained therefrom was purified by column chromatography, thereby obtaining Compound In-1 (yield: 87%).

[0318] High Resolution Mass Spectrometry (HRMS) for $\text{C}_{28}\text{H}_{21}\text{NO}_2$ $[\text{M}]^+$: calc: 403.48, found: 402.

Synthesis of In-2

[0319] 5 g of In-1 was dissolved in 15 g of triethylphosphite, and the mixed solution was stirred under reflux in a nitrogen atmosphere for 12 hours. After the reaction was completed, the reaction solution was subjected to a vacuum distillation process to remove unreacted triethylphosphite. The resulting solution was purified by column chromatography using a mixture of hexane and MC (4:1 (v/v)), thereby obtaining the desired compound, In-2 (yield: 51.4%).

[0320] HRMS for $\text{C}_{28}\text{H}_{21}\text{N}$ $[\text{M}]^+$: calc: 371.48, found: 370.

Synthesis Example 2: Synthesis of Compound ET-1

[0321] $\text{Pd}(\text{dba})_3$ (0.03 eq), $(\text{t-Bu})_3\text{P}$ (0.06 eq), and toluene (based on 0.1 M reagent (1 eq)) were added to a flask containing Int-2 (1 eq) and 2-bromo-4,6-diphenyl-1,3,5-triazine (1.2 eq). The mixed solution was stirred under reflux for 5 hours. The reaction solution was cooled to room temperature, and extraction was performed using MC, followed by washing using distilled water. The resulting solution was dried with MgSO_4 , filtered, and distilled under reduced pressure. The residue obtained therefrom was purified by column chromatography, thereby obtaining Compound ET-1 (yield: 76.1%).

[0322] HRMS for $\text{C}_{43}\text{H}_{30}\text{N}_4$ $[\text{M}]^+$: calc: 602.74, found: 601.

[0323] Elemental Analysis for $\text{C}_{43}\text{H}_{30}\text{N}_4$ calc: C, 85.69; H, 5.02; N, 9.30

Synthesis Example 3: Synthesis of Compound ET-2

[0324] $\text{Pd}(\text{dba})_3$ (0.03 eq), $(\text{t-Bu})_3\text{P}$ (0.06 eq), and toluene (based on 0.1 M reagent (1 eq)) were added to a flask containing Int-2 (1 eq) and 2-bromo-4,6-diphenylpyrimidine (1.2 eq), and the mixed solution was stirred under reflux for 5 hours. The reaction solution was cooled to room temperature, and extraction was performed using MC, followed by washing using distilled water. The resulting solution was dried with MgSO_4 , filtered, and distilled under reduced pressure. The residue obtained therefrom was purified by column chromatography, thereby obtaining Compound ET-2 (yield: 77.8%).

[0325] HRMS for $\text{C}_{44}\text{H}_{31}\text{N}_3$ $[\text{M}]^+$: calc: 601.75, found: 600.

[0326] Elemental Analysis for $\text{C}_{44}\text{H}_{31}\text{N}_3$ calc: C, 87.82; H, 5.19; N, 6.98

Synthesis Example 4: Synthesis of Compound ET-3

[0327] $\text{Pd}(\text{dba})_3$ (0.03 eq), $(\text{t-Bu})_3\text{P}$ (0.06 eq), and toluene (based on 0.1 M reagent (1 eq)) were added to a flask containing Int-2 (1 eq) and 4-bromo-2,6-diphenylpyrimidine

(1.2 eq), and the mixed solution was stirred under reflux for 5 hours. The reaction solution was cooled to room temperature, followed by extraction using methylene chloride (MC) and washing using distilled water. The resultant was dried with MgSO_4 , filtered, and distilled under reduced pressure. The residue obtained therefrom was purified by column chromatography, thereby obtaining Compound ET-3 (yield: 71.6%).

[0328] HRMS for $\text{C}_{44}\text{H}_{31}\text{N}_3$ $[\text{M}]^+$: calc: 601.75, found: 600.

[0329] Elemental Analysis for $\text{C}_{44}\text{H}_{31}\text{N}_3$ calc: C, 87.82; H, 5.19; N, 6.98

Synthesis Example 5: Synthesis of Compound ET-5

[0330] $\text{Pd}(\text{dba})_3$ (0.03 eq), $(\text{t-Bu})_3\text{P}$ (0.06 eq), and toluene (based on 0.1 M reagent (1 eq)) were added to a flask containing Int-2 (1 eq) and 4-bromo-2,6-diphenylpyridine (1.2 eq), and the mixed solution was stirred under reflux for 5 hours. The reaction solution was cooled to room temperature, and extraction was performed using MC, followed by washing using distilled water. The resulting solution was dried with MgSO_4 , filtered, and distilled under reduced pressure. The residue obtained therefrom was purified by column chromatography, thereby obtaining Compound ET-5 (yield: 74.1%).

[0331] HRMS for $\text{C}_{45}\text{H}_{32}\text{N}_2$ $[\text{M}]^+$: calc: 600.77, found: 599.

[0332] Elemental Analysis for $\text{C}_{45}\text{H}_{32}\text{N}_2$ calc: C, 89.97; H, 5.37; N, 4.66

Synthesis Example 6: Synthesis of Compound ET-7

[0333] $\text{Pd}(\text{dba})_3$ (0.03 eq), $(\text{t-Bu})_3\text{P}$ (0.06 eq), and toluene (based on 0.1 M reagent (1 eq)) were added to a flask containing Int-2 (1 eq) and 2-bromo-4,6-di(naphthalen-2-yl)pyridine (1.2 eq), and the mixed solution was stirred under reflux for 5 hours. The reaction solution was cooled to room temperature, and extraction was performed using MC, followed by washing using distilled water. The resulting solution was dried with MgSO_4 , filtered, and distilled under reduced pressure. The residue obtained therefrom was purified by column chromatography, thereby obtaining Compound ET-7 (yield: 71.9%).

[0334] HRMS for $\text{C}_{53}\text{H}_{36}\text{N}_2$ $[\text{M}]^+$: calc: 700.89, found: 699.

[0335] Elemental Analysis for $\text{C}_{53}\text{H}_{36}\text{N}_2$ calc: C, 90.83; H, 5.18; N, 4.00

Synthesis Example 7: Synthesis of Compound ET-13

[0336] $\text{Pd}(\text{dba})_3$ (0.03 eq), $(\text{t-Bu})_3\text{P}$ (0.06 eq), and toluene (0.1 M reagent (1 eq)) were added to a flask containing Int-2 (1 eq) and 2-(4-bromophenyl)-4,6-diphenyl-1,3,5-triazine (1.2 eq), and the mixed solution was stirred under reflux for 5 hours. The reaction solution was cooled to room temperature, and extraction was performed using MC, followed by washing using distilled water. The resulting solution was dried with MgSO_4 , filtered, and distilled under reduced pressure. The residue obtained therefrom was purified by column chromatography, thereby obtaining Compound ET-13 (yield: 69.4%).

[0337] HRMS for $\text{C}_{49}\text{H}_{34}\text{N}_4$ $[\text{M}]^+$: calc: 678.84, found: 677.

[0338] Elemental Analysis for $C_{49}H_{34}N_4$ calc: C, 86.70; H, 5.05; N, 8.25

Synthesis Example 8: Synthesis of Compound ET-14

[0339] $Pd(dba)_3$ (0.03 eq), $(t-Bu)_3P$ (0.06 eq), and toluene (0.1 M reagent (1 eq)) were added to a flask containing Int-2 (1 eq) and 2-(4-bromophenyl)-4,6-diphenylpyrimidine (1.2 eq), and the mixed solution was stirred under reflux for 5 hours. The reaction solution was cooled to room temperature, and extraction was performed using MC, followed by washing using distilled water. The resulting solution was dried with $MgSO_4$, filtered, and distilled under reduced pressure. The residue obtained therefrom was purified by column chromatography, thereby obtaining Compound ET-14 (yield: 66.7%).

[0340] HRMS for $C_{50}H_{35}N_3$ $[M]^+$: calc: 677.85, found: 676.

[0341] Elemental Analysis for $C_{50}H_{35}N_3$ calc: C, 88.60; H, 5.20; N, 6.20

Synthesis Example 9: Synthesis of Compound ET-16

[0342] $Pd(dba)_3$ (0.03 eq), $(t-Bu)_3P$ (0.06 eq), and toluene (0.1 M reagent (1 eq)) were added to a flask containing Int-2 (1 eq) and 2-(3-bromophenyl)-4,6-diphenyl-1,3,5-triazine (1.2 eq), and the mixed solution was stirred under reflux for 5 hours. The reaction solution was cooled to room temperature, and extraction was performed using MC, followed by washing using distilled water. The resulting solution was dried with $MgSO_4$, filtered, and distilled under reduced pressure. The residue obtained therefrom was purified by column chromatography, thereby obtaining Compound ET-16 (yield: 69.4%).

[0343] HRMS for $C_{49}H_{34}N_4$ $[M]^+$: calc: 678.84, found: 677.

[0344] Elemental Analysis for $C_{49}H_{34}N_4$ calc: C, 86.70; H, 5.05; N, 8.25

Synthesis Example 10: Synthesis of Compound ET-19

[0345] $Pd(dba)_3$ (0.03 eq), $(t-Bu)_3P$ (0.06 eq), and toluene (0.1 M reagent (1 eq)) were added to a flask containing Int-2 (1 eq) and (4-bromophenyl)diphenylphosphine oxide (1.2 eq), and the mixed solution was stirred under reflux for 5 hours. The reaction solution was cooled to room temperature, and extraction was performed using MC, followed by washing using distilled water. The resulting solution was dried with $MgSO_4$, filtered, and distilled under reduced pressure. The residue obtained therefrom was purified by column chromatography, thereby obtaining Compound ET-19 (yield: 69.4%).

[0346] HRMS for $C_{46}H_{34}NOP$ $[M]^+$: calc: 647.76, found: 646.

[0347] Elemental Analysis for $C_{49}H_{34}N_4$ calc: C, 85.30; H, 5.29; N, 2.16; O, 2.47; P, 4.78

Synthesis Example 11: Synthesis of Compound ET-20

[0348] $Pd(dba)_3$ (0.03 eq), $(t-Bu)_3P$ (0.06 eq), and toluene (0.1 M reagent (1 eq)) were added to a flask containing Int-2 (1 eq) and (3-bromophenyl)diphenylphosphine oxide (1.2 eq), and the mixed solution was stirred under reflux for 5

hours. The reaction solution was cooled to room temperature, and extraction was performed using MC, followed by washing using distilled water. The resulting solution was dried with $MgSO_4$, filtered, and distilled under reduced pressure. The residue obtained therefrom was purified by column chromatography, thereby obtaining Compound ET-20 (yield: 66.4%).

[0349] HRMS for $C_{46}H_{34}NOP$ $[M]^+$: calc: 647.76, found: 646.

[0350] Elemental Analysis for $C_{49}H_{34}N_4$ calc: C, 85.30; H, 5.29; N, 2.16; O, 2.47; P, 4.78

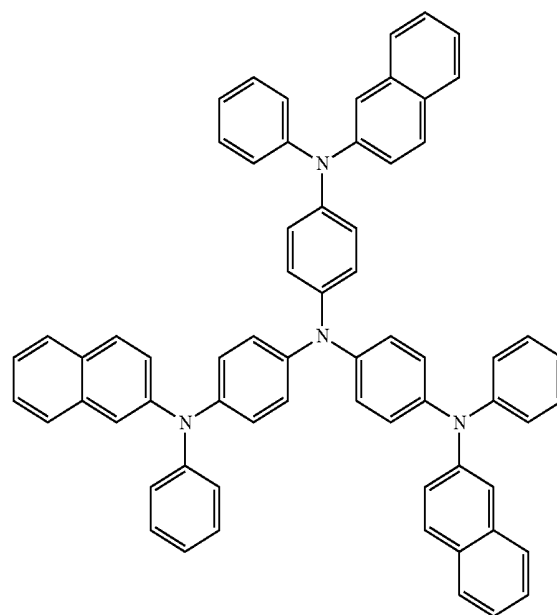
Example 1

[0351] An anode was prepared by cutting an indium tin oxide (ITO) glass substrate (manufactured by Corning) with ITO at a thickness of $15 \Omega/cm^2$ ($500 \text{ \AA}$) to a size of $50 \text{ mm} \times 50 \text{ mm} \times 0.5 \text{ mm}$, ultrasonically cleaning the ITO glass substrate using isopropyl alcohol and pure water for 10 minutes each, exposing to UV irradiation for 10 minutes, and cleaning with ozone. Then, the ITO glass substrate was loaded into a vacuum deposition apparatus.

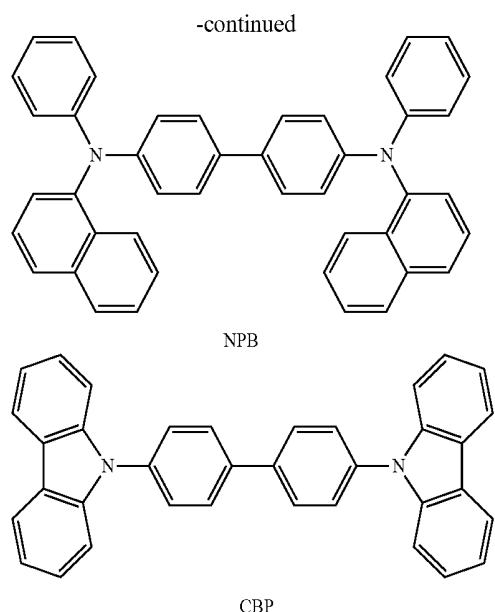
[0352] 2-TNATA was vacuum deposited on the ITO glass substrate to form a hole injection layer having a thickness of $600 \text{ \AA}$, and Compound NPB (which is a hole-transporting compound), was vacuum deposited on the hole injection layer to form a hole transport layer having a thickness of $300 \text{ \AA}$.

[0353] $Tris[2\text{-phenylpyridinato}]iridium(III)$ ($Ir(ppy)_3$) (which is a green phosphorescent dopant) and CBP were co-deposited on the hole transport layer at a weight ratio of 15:85 to form an emission layer having a thickness of $300 \text{ \AA}$.

[0354] Subsequently, Compound E-1 was deposited on the emission layer to form an electron transport layer having a thickness of $300 \text{ \AA}$, and Al was deposited on the electron transport layer to form an Al electrode (i.e., a negative electrode) having a thickness of $1,200 \text{ \AA}$, thereby completing the manufacture of an organic light-emitting device.



2-TNATA



Example 2

[0355] An organic light-emitting device was manufactured in substantially the same manner as in Example 1, except that Compound E-2 was used instead of Compound E-1 in forming the electron transport layer.

Example 3

[0356] An organic light-emitting device was manufactured in substantially the same manner as in Example 1, except that Compound E-3 was used instead of Compound E-1 in forming the electron transport layer.

Example 4

[0357] An organic light-emitting device was manufactured in substantially the same manner as in Example 1, except that Compound E-5 was used instead of Compound E-1 in forming the electron transport layer.

Example 5

[0358] An organic light-emitting device was manufactured in substantially the same manner as in Example 1, except that Compound E-7 was used instead of Compound E-1 in forming the electron transport layer.

Example 6

[0359] An organic light-emitting device was manufactured in substantially the same manner as in Example 1, except that Compound E-13 was used instead of Compound E-1 in forming the electron transport layer.

Example 7

[0360] An organic light-emitting device was manufactured in substantially the same manner as in Example 1, except that Compound E-14 was used instead of Compound E-1 in forming the electron transport layer.

Example 8

[0361] An organic light-emitting device was manufactured in substantially the same manner as in Example 1, except that Compound E-16 was used instead of Compound E-1 in forming the electron transport layer.

Example 9

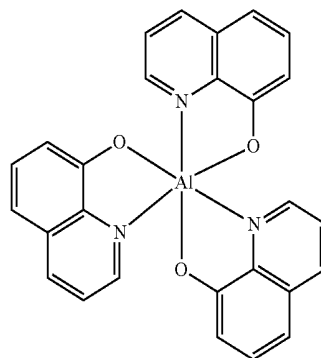
[0362] An organic light-emitting device was manufactured in substantially the same manner as in Example 1, except that Compound E-19 was used instead of Compound E-1 in forming the electron transport layer.

Example 10

[0363] An organic light-emitting device was manufactured in substantially the same manner as in Example 1, except that Compound E-20 was used instead of Compound E-1 in forming the electron transport layer.

Comparative Example 1

[0364] An organic light-emitting device was manufactured in substantially the same manner as in Example 1, except that Compound Alq₃ was used instead of Compound E-1 in forming the electron transport layer.

Compound Alq₃

[0365] The efficiency and lifespan (T₉₅) of each of the organic light-emitting devices of Examples 1 to 10 and Comparative Example were measured, and the results thereof are shown in Table 1.

TABLE 1

	Material for forming an electron transport layer	Efficiency (cd/A)	Lifespan (T ₉₅) (@ 3700 nit)
Example 1	ET-1	51	923
Example 2	ET-2	48.8	911
Example 3	ET-3	47.7	897
Example 4	ET-5	47.9	921
Example 5	ET-7	49.2	943
Example 6	ET-13	48.0	937
Example 7	ET-14	47.9	956
Example 8	ET-16	42	942
Example 9	ET-19	46.4	965
Example 10	ET-20	42.7	970

TABLE 1-continued

	Material for forming an electron transport layer	Efficiency (cd/A)	Lifespan (T95) (@ 3700 nit)
Comparative Example	Alq3	38.4	789

[0366] Compounds having the structure of Formula 1 according to an embodiment of the present disclosure were used as electron-transporting materials, and consequently, all the organic light-emitting devices including these compounds showed significantly improved characteristics, for example, increased lifespan characteristics, compared to the organic light-emitting device of Comparative Example 1. Accordingly, it was confirmed that the compounds having the structure of Formula 1 according to the present disclosure were excellent electron-transporting materials with significant effects.

[0367] An organic light-emitting device according to an embodiment of the present disclosure may have high efficiency, low driving voltage, high brightness, and long lifespan.

[0368] It should be understood that the embodiments described herein should be considered in a descriptive sense only and not for purposes of limitation. Descriptions of features or aspects within each embodiment should typically be considered as being available for other similar features or aspects in other embodiments.

[0369] 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.

[0370] 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.

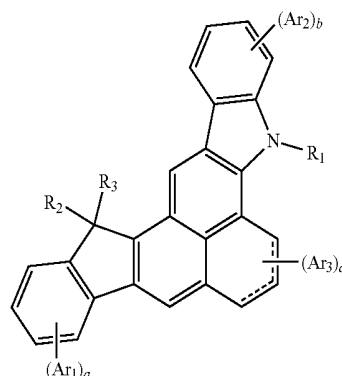
[0371] Also, any numerical range recited herein is intended to include all sub-ranges of the same numerical precision subsumed within the recited range. For example, a range of “1.0 to 10.0” is intended to include all subranges between (and including) the recited minimum value of 1.0 and the recited 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.

[0372] While one or more embodiments have been described with reference to the drawings, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present disclosure as defined by the following claims and equivalents thereof.

What is claimed is:

1. A compound represented by Formula 1:

Formula 1



wherein, in Formula 1,

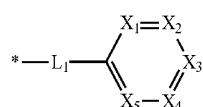
R_2 and R_3 are each independently selected from hydrogen, deuterium, a halogen atom, a nitro group, a cyano group, a substituted or unsubstituted C_1 - C_{60} alkyl group, a substituted or unsubstituted C_2 - C_{60} alkenyl group, a substituted or unsubstituted C_2 - C_{60} alkynyl group, a substituted or unsubstituted C_1 - C_{60} alkoxy group, a substituted or unsubstituted C_3 - C_{10} cycloalkyl group, a substituted or unsubstituted C_2 - C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3 - C_{10} cycloalkenyl group, a substituted or unsubstituted C_2 - 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,

Ar_1 to Ar_3 are each independently selected from hydrogen, deuterium, a substituted or unsubstituted C_6 - C_{60} aryl group, a substituted or unsubstituted C_6 - C_{60} aryloxy group, a substituted or unsubstituted C_6 - C_{60} arylthio group, a substituted or unsubstituted C_1 - C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, a substituted or unsubstituted C_5 - C_{60} carbocyclic group, and a substituted or unsubstituted C_1 - C_{60} heterocyclic group,

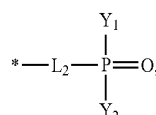
a to c are each independently an integer selected from 0 to 2,

R_1 is one selected from Formulae 1-1 and 1-2:

Formula 1-1



Formula 1-2



wherein, in Formulae 1-1 and 1-2,

X₁ to X₅ are each independently selected from nitrogen (N) and CR₁₁,

at least one selected from X₁ to X₅ is N,

R₁₁, Y₁, and Y₂ are each independently selected from a substituted or unsubstituted C₁-C₆₀ alkyl group, a substituted or unsubstituted C₆-C₆₀ aryl group, a substituted or unsubstituted C₁-C₆₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group,

L₁ and L₂ are each independently selected from a substituted or unsubstituted C₆-C₆₀ arylene group, a substituted or unsubstituted C₁-C₆₀ heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

* indicates a binding site, and

at least one substituent selected from the substituted C₁-C₆₀ alkyl group, the substituted C₂-C₆₀ alkenyl group, the substituted C₂-C₆₀ alkynyl group, the substituted C₁-C₆₀ alkoxy group, the substituted C₃-C₁₀ cycloalkyl group, the substituted C₂-C₁₀ heterocycloalkyl group, the substituted C₃-C₁₀ cycloalkenyl group, the substituted C₂-C₁₀ heterocycloalkenyl group, the substituted C₆-C₆₀ aryl group, the substituted C₆-C₆₀ aryloxy group, the substituted C₆-C₆₀ arylthio group, the substituted C₁-C₆₀ heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, the substituted monovalent non-aromatic condensed heteropolycyclic group, the substituted C₅-C₆₀ carbocyclic group, the substituted C₁-C₆₀ heterocyclic group, the substituted C₆-C₆₀ arylene group, the substituted C₁-C₆₀ heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, and the substituted divalent non-aromatic condensed heteropolycyclic group is selected from the group consisting of:

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;

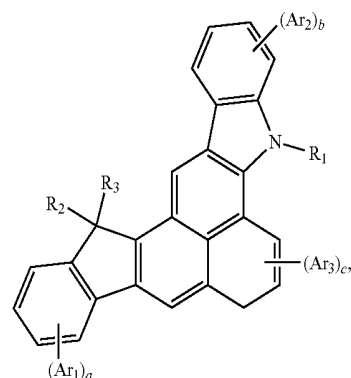
a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ heteroaryl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a 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 C₂-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₂-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),

a C₃-C₁₀ cycloalkyl group, a C₂-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₂-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; and

a C₃-C₁₀ cycloalkyl group, a C₂-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₂-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 C₂-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₂-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),

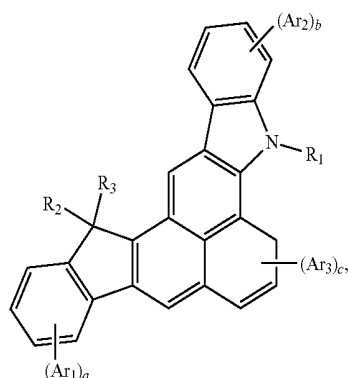
wherein Q₁₁ to Q₁₇ and Q₂₁ to Q₂₇ are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt 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 C₂-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₂-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.

2. The compound of claim 1, wherein the compound represented by Formula 1 is represented by Formula 2:



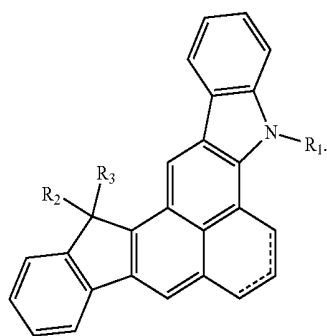
Formula 2

3. The compound of claim 1, wherein the compound represented by Formula 1 is represented by Formula 3:



Formula 3

4. The compound of claim 1, wherein the compound represented by Formula 1 is represented by Formula 4:



Formula 4

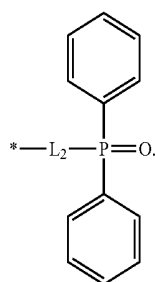
5. The compound of claim 1, wherein X₁ or X₃ in Formula 1-1 is N.

6. The compound of claim 1, wherein X₁ and X₅ in Formula 1-1 are each independently N.

7. The compound of claim 1, wherein X₁ and X₃ in Formula 1-1 are each independently N.

8. The compound of claim 1, wherein X₁, X₃, and X₅ in Formula 1-1 are each independently N.

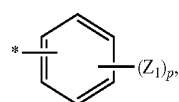
9. The compound of claim 1, wherein the group represented by Formula 1-2 is represented by Formula 1-3:



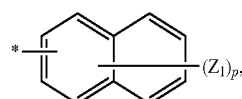
Formula 1-3

10. The compound of claim 1, wherein R₂ and R₃ are each independently selected from a substituted or unsubstituted C₁-C₂₀ alkyl group.

11. The compound of claim 1, wherein R₁₁ is represented by one selected from Formulae 2a to 2b:



2a



2b

wherein, in Formulae 2a to 2b,

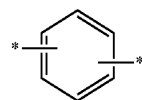
Z₁ is selected from hydrogen, deuterium, a halogen group, a cyano group, a nitro group, a hydroxyl group, a carboxyl group, a substituted or unsubstituted C₁-C₂₀ alkyl group, a substituted or unsubstituted C₆-C₂₀ aryl group, a substituted or unsubstituted C₁-C₂₀ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group,

p is an integer selected from 1 to 7,

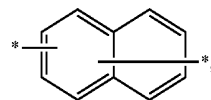
when p is 2 or greater, a plurality of Z₁(s) are identical to or different from each other, and

* indicates a binding site.

12. The compound of claim 1, wherein L₁ and L₂ are each independently represented by one selected from Formulae 3a to 3b:



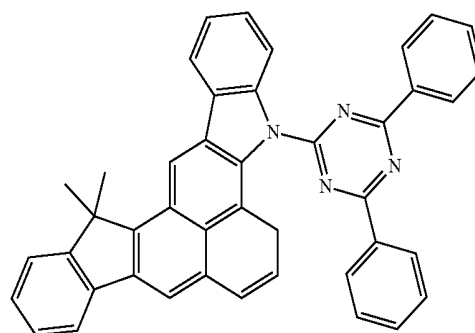
3a



3b

wherein, in Formulae 3a to 3b, * indicates a binding site.

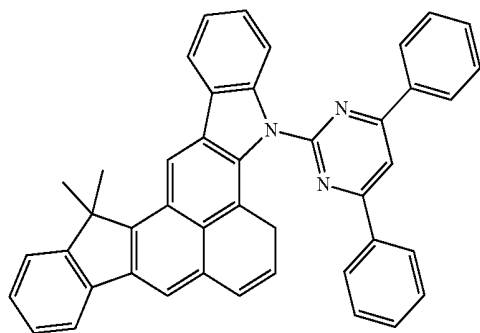
13. The compound of claim 1, wherein the compound of Formula 1 is one selected from Compounds ET1 to ET42:



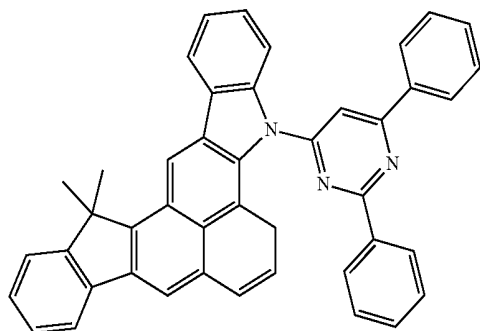
ET-1

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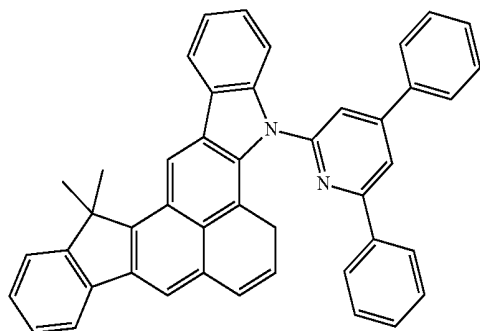
ET-2



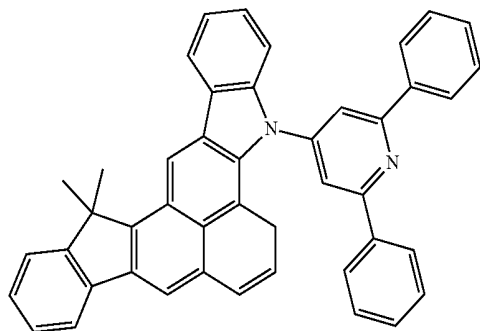
ET-3



ET-4

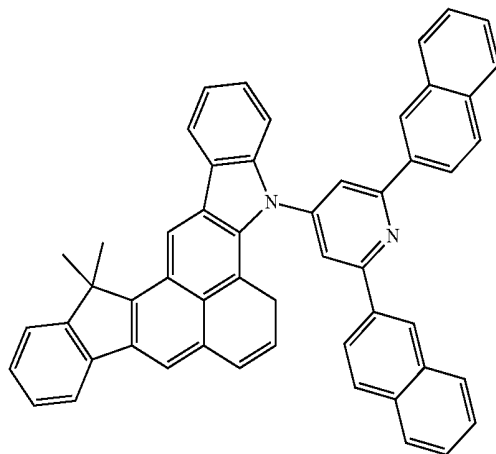


ET-5

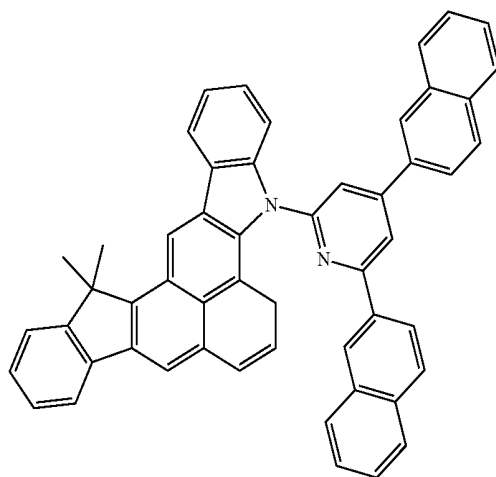


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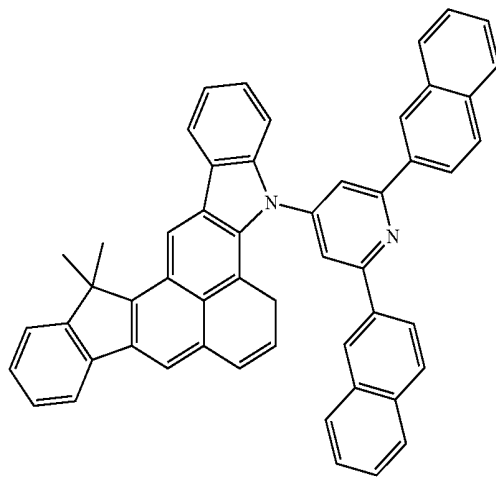
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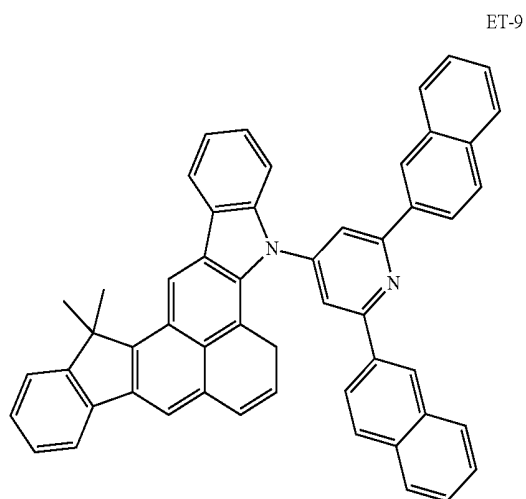
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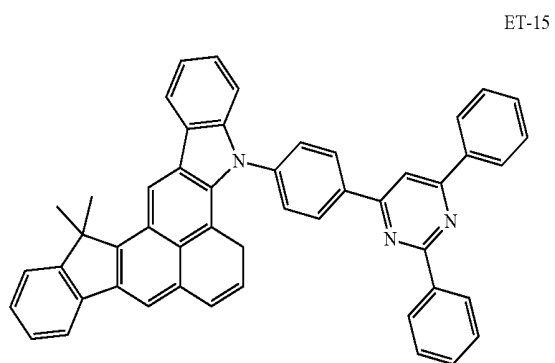
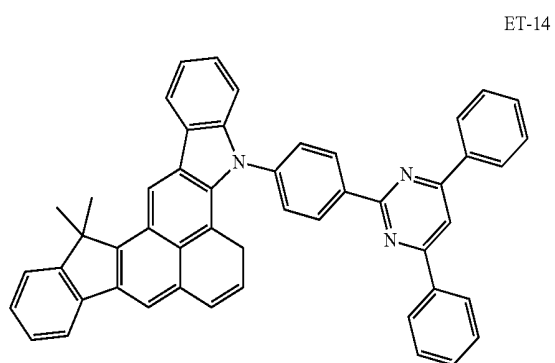
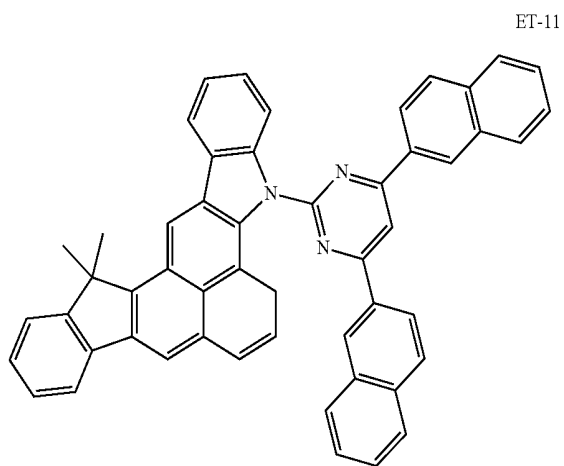
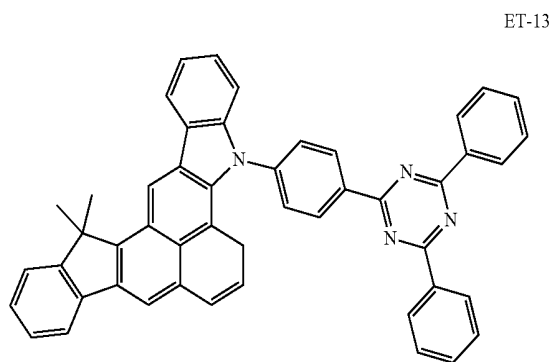
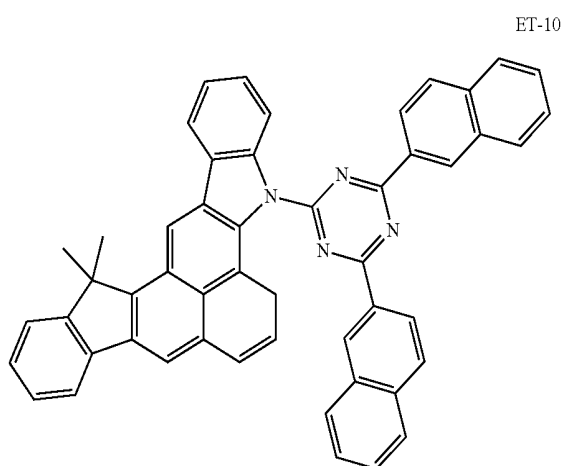
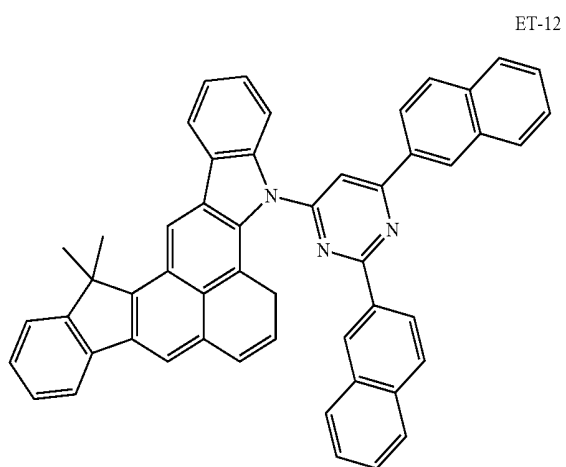
ET-8



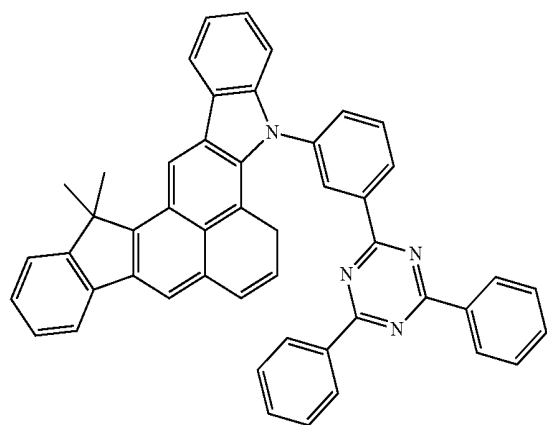
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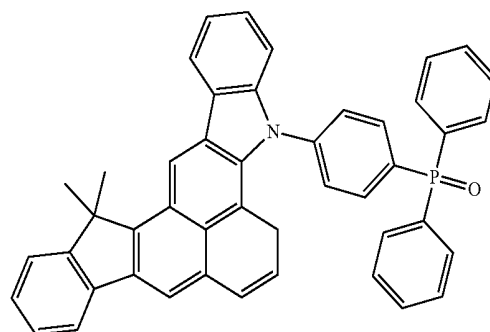


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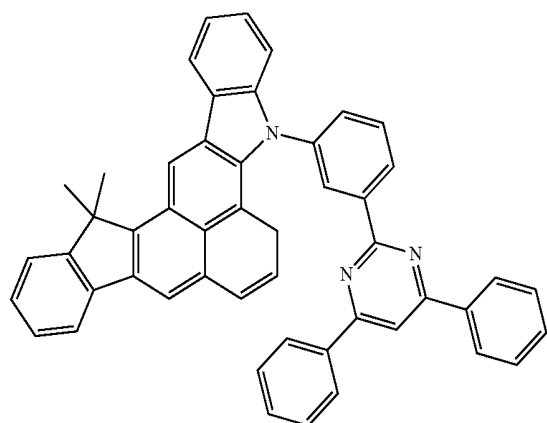


ET-16

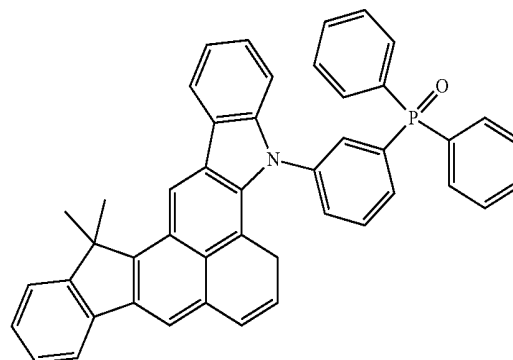
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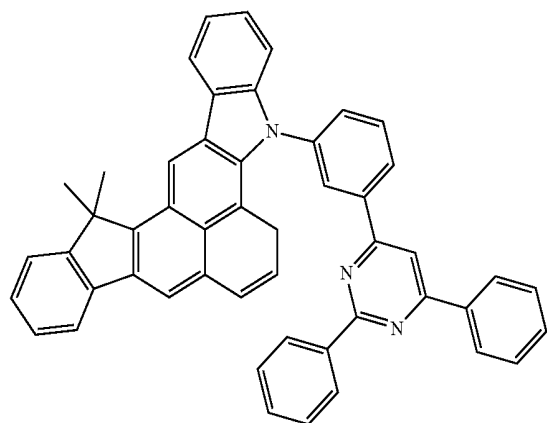
ET-19



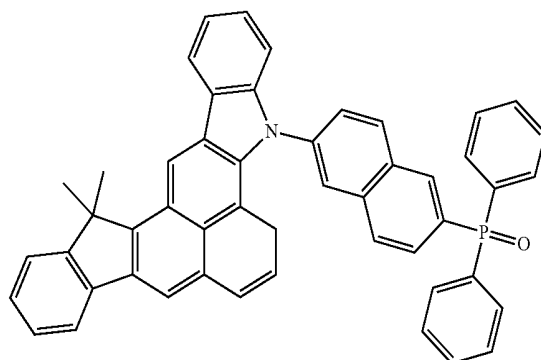
ET-17



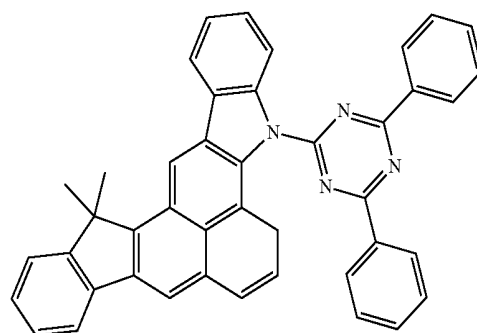
ET-20



ET-18



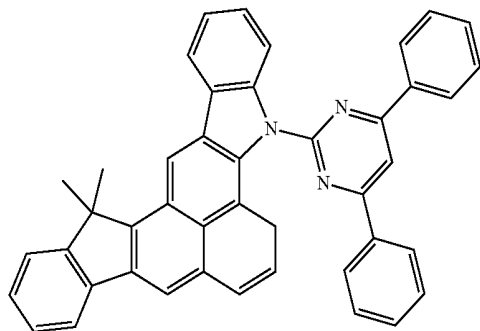
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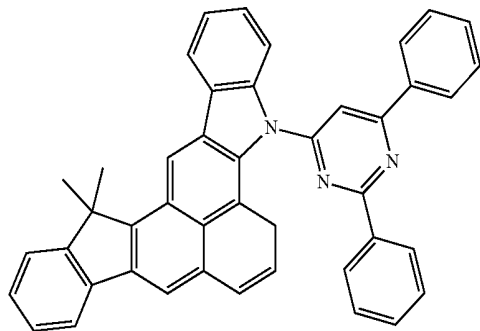
ET-22

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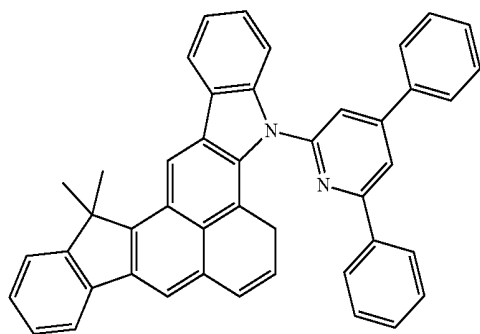
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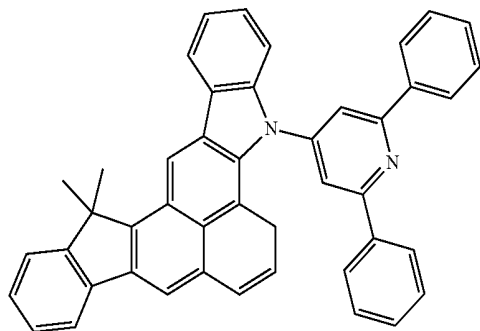
ET-24



ET-25

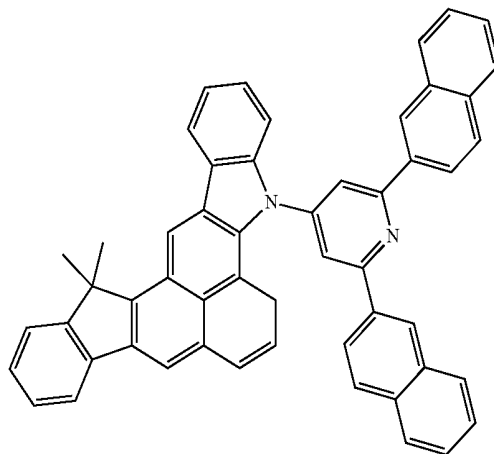


ET-26

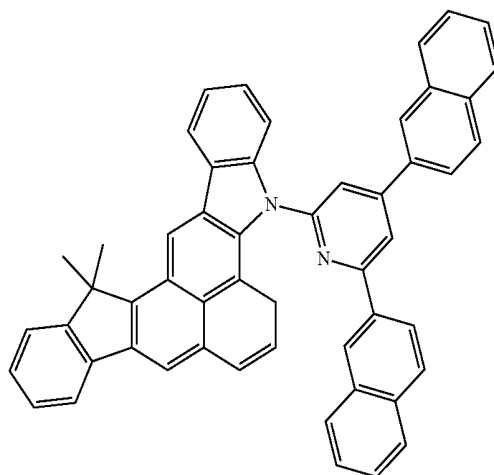


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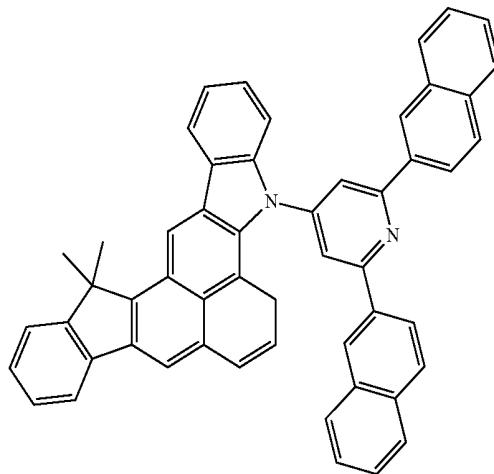
ET-27



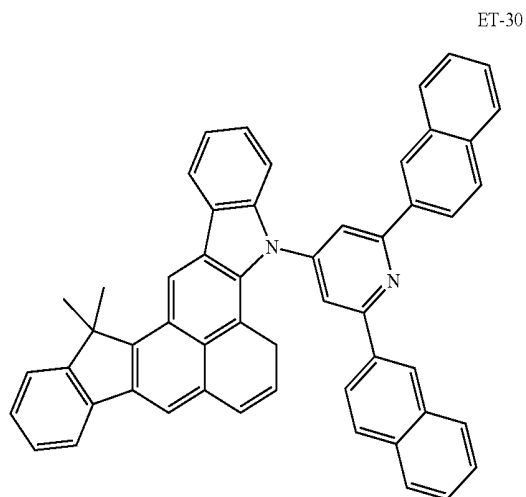
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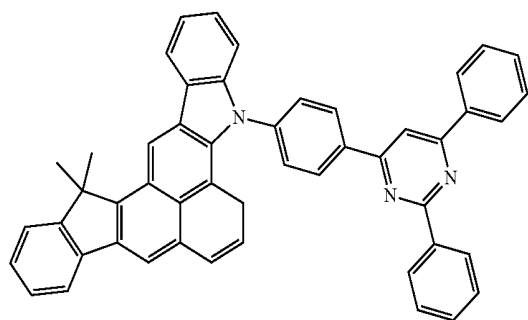
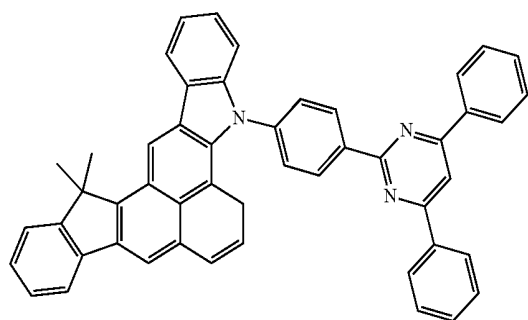
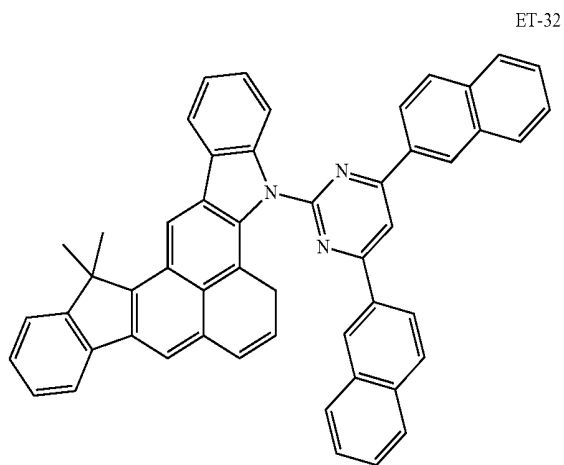
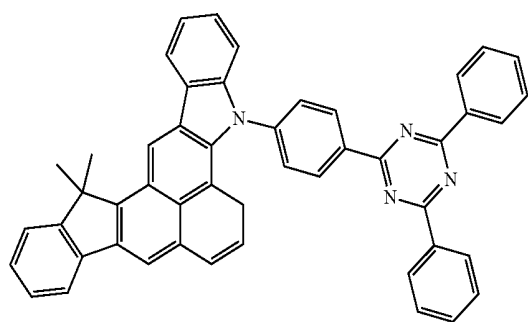
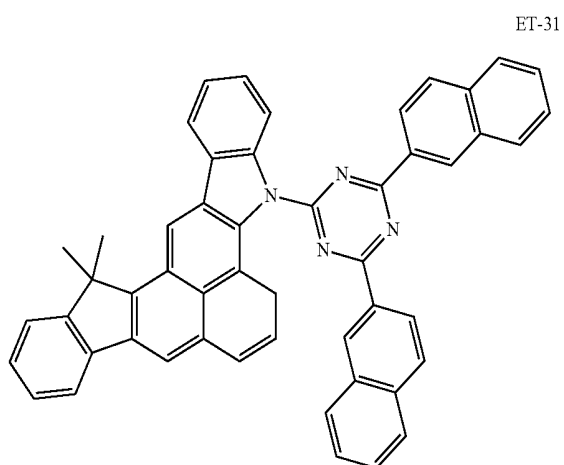
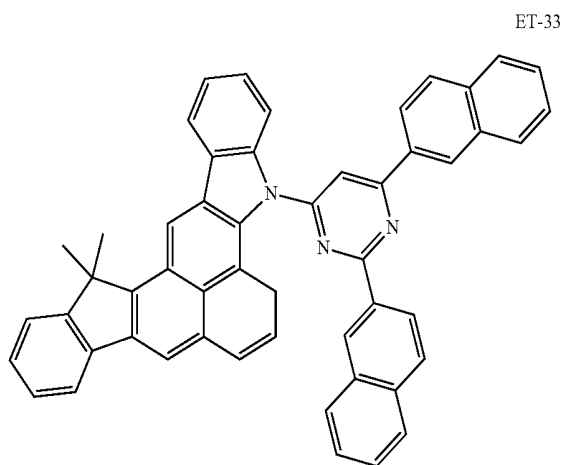
ET-29



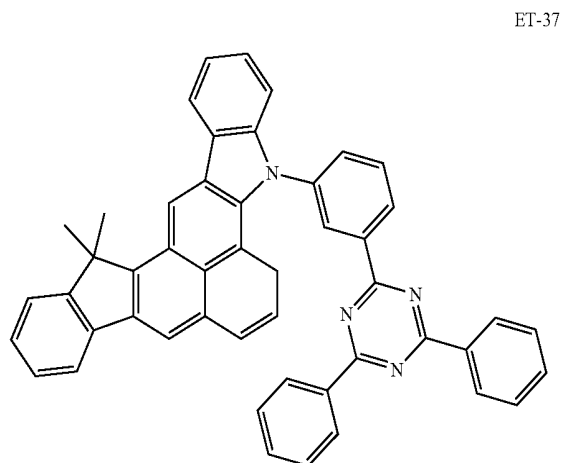
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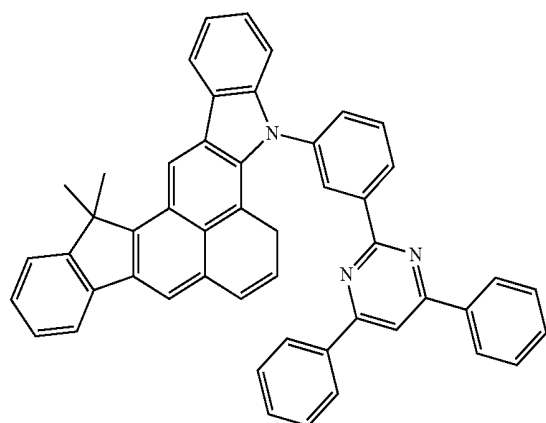
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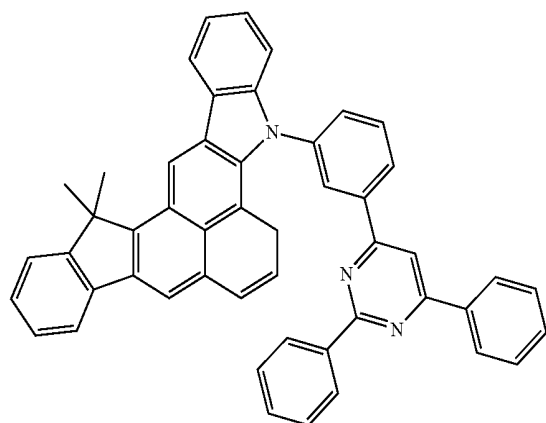
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ET-38

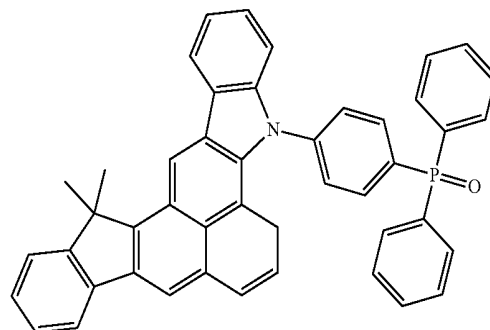


ET-39

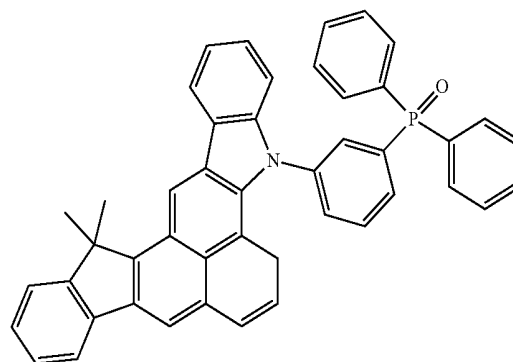


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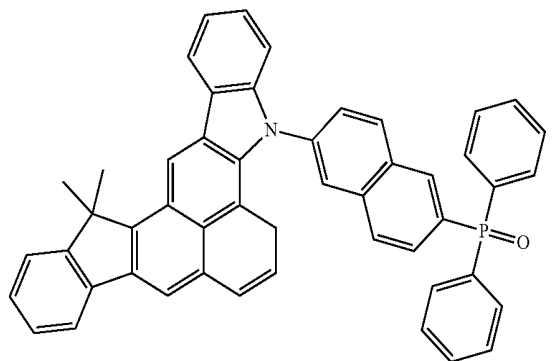
ET-40



ET-41



ET-42

**14.** An organic light-emitting device comprising:

a first electrode;

a second electrode facing the first electrode; and

an organic layer between the first electrode and the second electrode, the organic layer comprising an emission layer,

wherein the organic layer comprises the compound of claim 1.

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

the first electrode is an anode,

the second electrode is a cathode, and

the organic layer comprises:

i) a hole transport region between the first electrode and the emission layer, the hole transport region comprising at least one selected from a hole transport layer, a hole injection layer, and an electron blocking layer; and

ii) an electron transport region between the emission layer and the second electrode, the electron transport region

comprising an electron transport layer and at least one selected from a hole blocking layer and an electron injection layer.

16. The organic light-emitting device of claim **15**, wherein the electron transport region comprises the compound represented by Formula 1.

17. The organic light-emitting device of claim **15**, wherein the electron transport layer comprises the compound represented by Formula 1.

18. The organic light-emitting device of claim **15**, wherein the hole transport region comprises a charge-generation material.

19. The organic light-emitting device of claim **18**, wherein the charge-generation material is a p-dopant.

20. A display apparatus comprising the organic light-emitting device of claim **14**, wherein the first electrode of the organic light-emitting device is electrically connected to a source electrode or a drain electrode of a thin film transistor.

* * * * *

专利名称(译)	复合和有机发光器件		
公开(公告)号	US20170155056A1	公开(公告)日	2017-06-01
申请号	US15/174918	申请日	2016-06-06
[标]申请(专利权)人(译)	三星显示有限公司		
申请(专利权)人(译)	三星DISPLAY CO. , LTD.		
当前申请(专利权)人(译)	三星DISPLAY CO. , LTD.		
[标]发明人	LEE JUNGSUB KIM SEULONG KIM YOUNSUN SHIN DONGWOO ITO NAOYUKI LIM JINO		
发明人	LEE, JUNGSUB KIM, SEULONG KIM, YOUNSUN SHIN, DONGWOO ITO, NAOYUKI LIM, JINO		
IPC分类号	H01L51/00 C07F9/572 C07D401/04 C07D403/10 H01L27/32 C07D403/04		
CPC分类号	H01L51/0072 H01L27/3248 C07D403/10 C07F9/5728 H01L51/5072 H01L51/0058 H01L51/56 C07D403/04 H01L51/0067 C07D401/04 H01L51/506 H01L51/0085 H01L2251/308		
优先权	1020150166413 2015-11-26 KR		
其他公开文献	US9899610		
外部链接	Espacenet USPTO		

摘要(译)

一种有机发光装置，包括：第一电极;面向第一电极的第二电极;第一电极和第二电极之间的有机层，有机层包括发光层，其中有机层包括由式1表示的化合物：当式1的化合物用作电子传输材料时，包含该化合物的有机发光装置可具有高效率，低驱动电压，高亮度和长寿命。

