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

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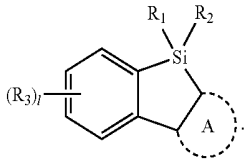
(57) **ABSTRACT**

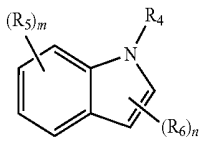
A compound having a high glass transition temperature, high electric stability, and/or high luminescent efficiency, and an organic light-emitting device including an emitting layer including the compound, which is represented by Formula 1:

Formula 1

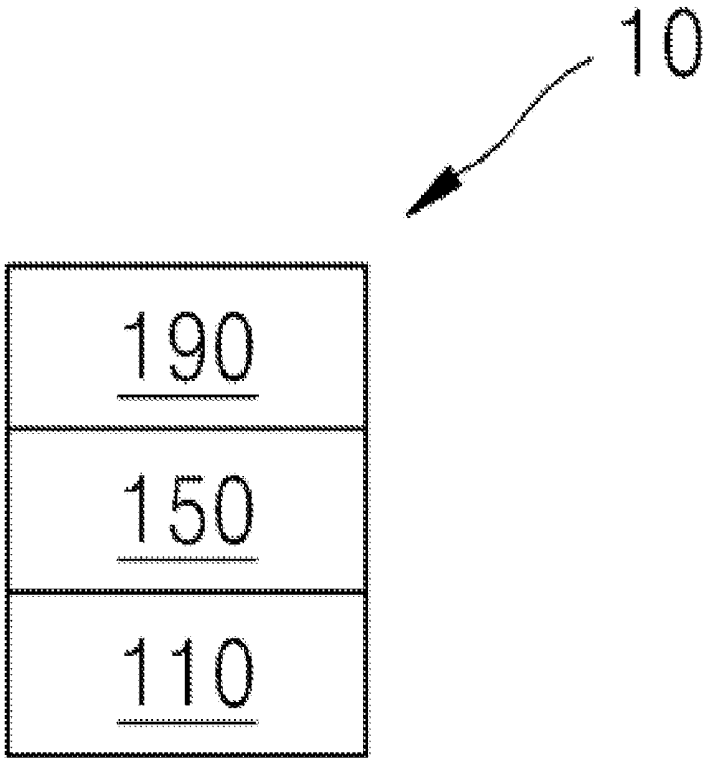


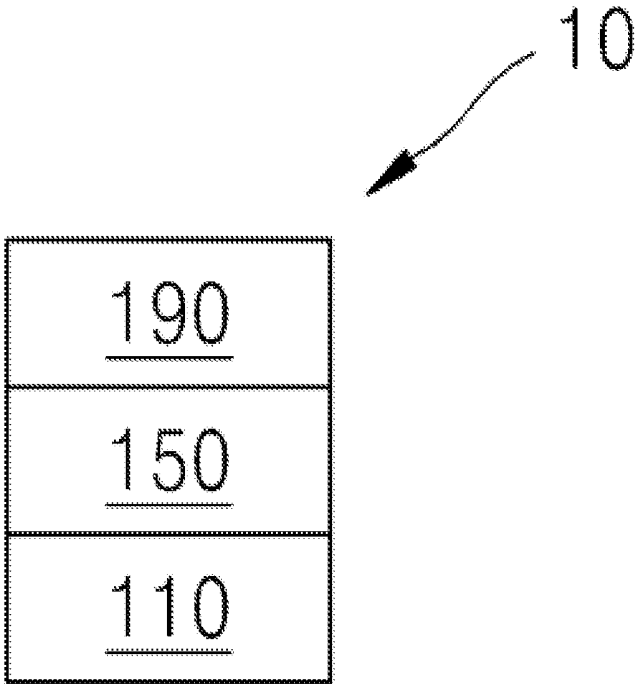
In Formula 1, A may be a moiety formed by fusing a substituted or unsubstituted indole group, as represented by Formula 1-1:

Formula 1-1



When the compound represented by Formula 1 is used as a material for an emitting layer, an organic light emitting device including the compound may exhibit decreased driving voltage and improved efficiency and lifespan, as compared to OLEDs containing compounds that are available in the related art.




10
190
150
110

COMPOUND AND ORGANIC LIGHT-EMITTING DEVICE INCLUDING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to and the benefit of Korean Patent Application No. 10-2015-0124952, filed on Sep. 3, 2015, in the Korean Intellectual Property Office, the entire content of which is incorporated herein by reference.

BACKGROUND

[0002] 1. Field

[0003] 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.

[0004] 2. Description of the Related Art

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

[0006] An organic light-emitting device may include a first electrode on a substrate, and a hole transport region, an emitting 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 emitting layer through the hole transport region, and electrons provided from the second electrode may move toward the emitting layer through the electron transport region. Carriers (such as holes and electrons) may recombine in the emitting layer to produce excitons. These excitons may change (e.g., decay or transition) from an excited state to a ground state to thereby generate light.

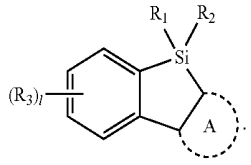
SUMMARY

[0007] One or more aspects of example embodiments of the present disclosure are directed toward a compound having a high glass transition temperature, high electric stability, and/or high luminescent efficiency, and an organic light-emitting device including an emitting layer including the compound.

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

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

Formula 1



[0010] In Formula 1,

[0011] R_1 to R_3 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 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;

[0012] A may indicate a moiety formed by fusing a substituted or unsubstituted indole group;

[0013] I may be an integer selected from 0 to 4; and

[0014] at least one substituent of the substituted C_1-C_{60} alkyl group, substituted C_2-C_{60} alkenyl group, substituted C_2-C_{60} alkynyl group, substituted C_1-C_{60} alkoxy group, substituted C_3-C_{10} cycloalkyl group, substituted C_2-C_{10} heterocycloalkyl group, substituted C_3-C_{10} cycloalkenyl group, substituted C_2-C_{10} heterocycloalkenyl group, substituted C_6-C_{60} aryl group, substituted C_6-C_{60} aryloxy group, substituted C_6-C_{60} arylthio group, substituted C_2-C_{60} heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from the group consisting of:

[0015] 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;

[0016] 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_2-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 $—B(Q_{16})(Q_{17})$,

[0017] 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_2-C_{60} heteroaryl

group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group; and

[0018] 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_2-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_2-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 $—B(Q_{26})(Q_{27})$,

[0019] 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.

[0020] According to one or more example embodiments of the present disclosure, an organic light-emitting device includes: a first electrode; a second electrode facing the first electrode; and an organic layer between the first electrode and the second electrode and including an emitting layer, wherein the organic layer includes the compound described above.

[0021] According to one or more example embodiments of the present disclosure, a flat panel display apparatus includes the organic light-emitting device, 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.

BRIEF DESCRIPTION OF THE DRAWING

[0022] These and/or other aspects will become apparent and more readily appreciated from the following description of example embodiments, taken in conjunction with the accompanying drawing, which illustrates a schematic view of an organic light-emitting device according to one or more embodiments of the present disclosure.

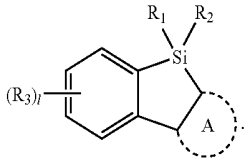
DETAILED DESCRIPTION

[0023] Reference will now be made in more detail to example embodiments, examples of which are illustrated in the accompanying drawing, wherein like reference numerals refer to like elements throughout and duplicative descriptions thereof may not be provided. In this regard, the present example embodiments may have different forms and should not be construed as being limited to the descriptions set forth herein. Accordingly, the example embodiments are merely described below, by referring to the drawing, to explain aspects of the present description. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items. Expressions such as "at least one of", "one of", "at least one selected from", and "one selected from" when preceding a list of elements, modify the entire list of elements and do not modify the individual elements of the list.

[0024] In the drawing, the thickness of layers, films, panels, regions, etc., may be exaggerated for clarity. It will be understood that when an element such as a layer, film, region, or substrate is referred to as being "on" another element, it can be directly on the other element or intervening element(s) may also be present. In contrast, when an element is referred to as being "directly on" another element, no intervening elements are present.

[0025] A compound according to an example embodiment of the present disclosure may be represented by Formula 1:

Formula 1



[0026] In Formula 1,

[0027] R_1 to R_3 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 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;

[0028] A may be a moiety formed by fusing a substituted or unsubstituted indole group;

[0029] I may be an integer selected from 0 to 4; and

[0030] at least one substituent of the substituted C_1-C_{60} alkyl group, substituted C_2-C_{60} alkenyl group, substituted C_2-C_{60} alkynyl group, substituted C_1-C_{60} alkoxy group, substituted C_3-C_{10} cycloalkyl group, substituted C_2-C_{10} heterocycloalkyl group, substituted C_3-C_{10} cycloalkenyl group,

substituted C_2-C_{10} heterocycloalkenyl group, substituted C_6-C_{60} aryl group, substituted C_6-C_{60} aryloxy group, substituted C_6-C_{60} arylthio group, substituted C_2-C_{60} heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from the group consisting of:

[0031] 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;

[0032] 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_2-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 —$B(Q_{16})(Q_{17})$,

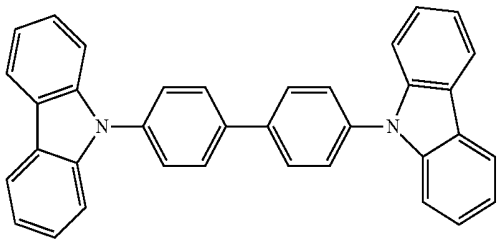
[0033] a C_3-C_{10} cycloalkyl group, a C_2-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_2-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group; and

[0034] 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_2-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_2-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 —$B(Q_{26})(Q_{27})$,

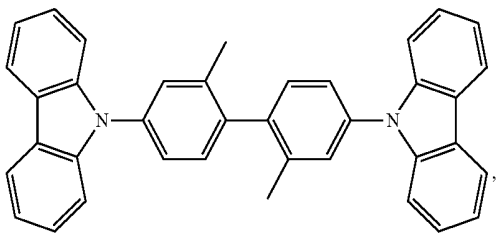
[0035] wherein Q_{11} to Q_{17}, and Q_{21} to Q_{27} may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic 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.

[0036] RGB luminescent materials may be used to embody a full-color organic light-emitting device (OLED) display. To improve the characteristics of an OLED, it is important to develop RGB luminescent materials having high efficiencies and long lifespans. Luminescent materials can be classified as host materials and dopant materials, according to their function. In the structure of a device having excellent electroluminescent characteristics, a dopant may be doped into a host during manufacturing of an emitting layer. As demands for OLEDs having high efficiencies and long lifespans increase, and in particular, when the level of electroluminescent characteristics required by middle- or large-sized OLED panels are taken into consideration, there is a need to develop luminescent materials having excellent characteristics compared to existing luminescent materials.

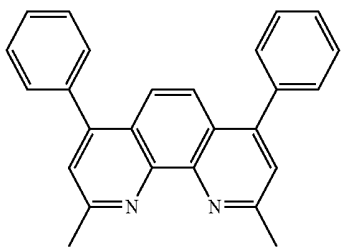
[0037] CBP and CDBP are widely used as phosphorescent host materials in the related art. A high-efficiency OLED including a hole blocking layer including BCP and/or BAlq is available in the related art. A high-performance OLED using a BAlq derivative as a host is available in the related art.



CBP



CDBP



BCP

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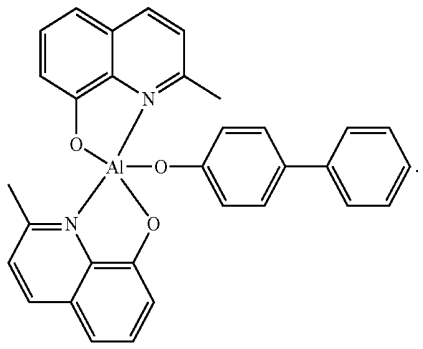
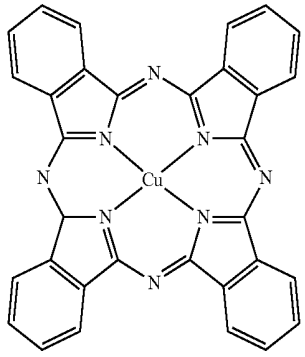
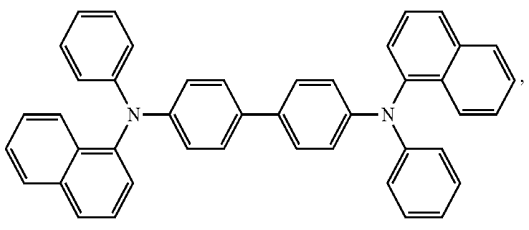


BAlq

[0038] Non-limiting examples of a hole injection and/or transport material may include copper phthalocyanine (CuPc), 4,4'-bis[N-(1-naphthyl)-N-phenylamino]-biphenyl (NPB), 4,4',4"-Tris(N-3-methylphenyl-N-phenyl-amino)triphenylamine (m-MTDATA), and 4,4',4"-Tris(N-(2-naphthyl)-N-phenyl-amino)triphenylamine (2T-NATA). When a compound having a higher thin-film stability and a higher degree of amorphousness is included in an OLED, the OLED may have higher durability. The glass transition temperature (Tg) of a material may be used as an index for the degree of amorphousness. For example, the glass transition temperature of m-MTDATA is 76° C., and the amorphousness of m-MTDATA is accordingly low. Due to the relatively low degree of amorphousness, a OLED manufactured with m-MTDATA may not have satisfactory durability and/or luminescent efficiency characteristics, based on its hole injection and hole transport characteristics.

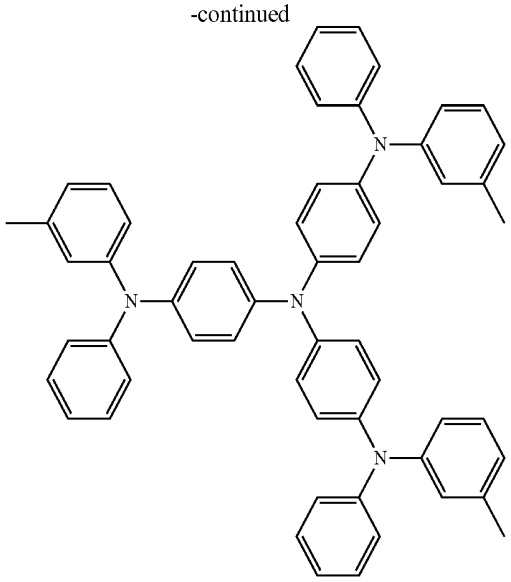


CuPc

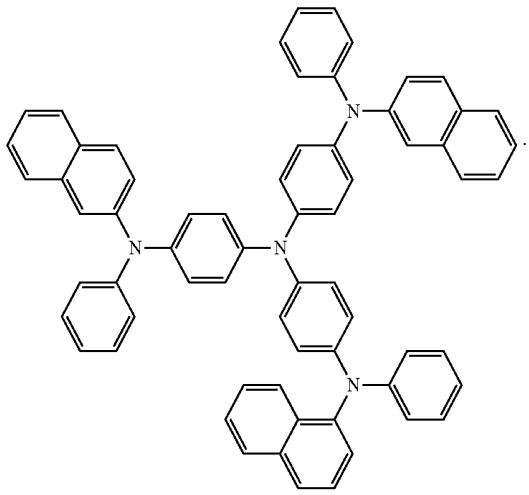


NPB

-continued



m-MTDATA



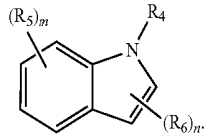
2T-NATA

[0039] Luminescent materials in the related art may display satisfactory luminescent characteristics. However, due to their low glass transition temperatures and low thermal stabilities, the physical properties of these materials may change when a high temperature deposition process is performed under vacuum. When CBP is used as a phosphorescent luminescent host material, the driving voltage may be high and the power efficiency may be accordingly low, compared to an OLED using a fluorescent host material. In some embodiments, the OLED including CBP may have an unsatisfactory lifespan. Accordingly, there is a need to develop a host material with high stability and high performance.

[0040] In some embodiments, a plurality of adjacent R_3 groups may be connected (e.g., coupled) to each other to form a ring.

[0041] In some embodiments, A in Formula 1 may indicate a moiety formed by fusing Formula 1-1:

Formula 1-1



[0042] In Formula 1-1, R_5 and R_6 may each be the same as described herein in connection with R_1 to R_3;

[0043] m may be an integer selected from 0 to 4; and n may be an integer selected from 0 to 2.

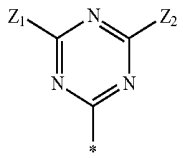
[0044] In some embodiments, A in Formula 1 indicates a moiety formed by fusing a phenyl moiety in Formula 1-1; and m may be an integer selected from 0 to 2.

[0045] In some embodiments, R_1 and R_2 may each independently be selected from a phenyl group, a biphenyl group, a terphenyl group, and a methyl group.

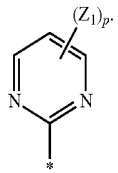
[0046] In some embodiments, R_3 and R_6 may each independently be selected from hydrogen and deuterium.

[0047] In some embodiments, R_4 may be selected from the following formulae:

2a



2b



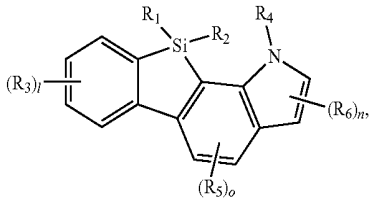
[0048] In the above formulae, Z_1 and Z_2 may each independently be selected from hydrogen, deuterium, a halogen group, a cyano group, a nitro group, a hydroxyl group, a carboxy group, a substituted or unsubstituted C_1 to C_{20} alkyl group, a substituted or unsubstituted C_6 to C_{20} aryl group, a substituted or unsubstituted C_1 to 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;

[0049] p may be an integer selected from 1 to 3; * may indicate a binding site, and

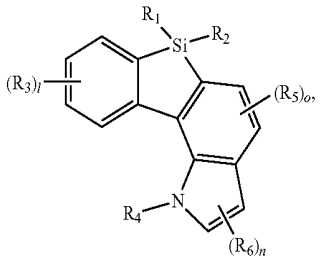
[0050] when p is two or more, each Z_1 group may be identical to or different from each other.

[0051] In some embodiments, Formula 1 may be further represented by one selected from Formulae 2 to 7:

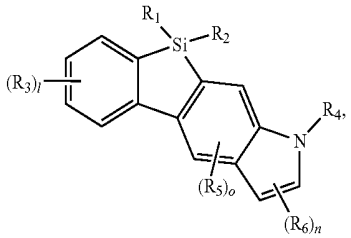
Formula 2



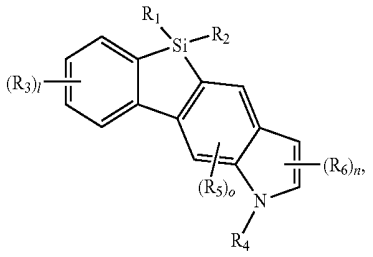
Formula 3



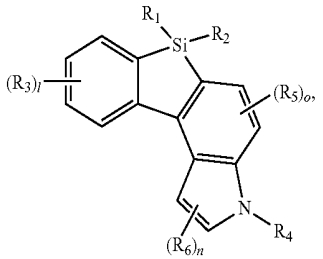
Formula 4



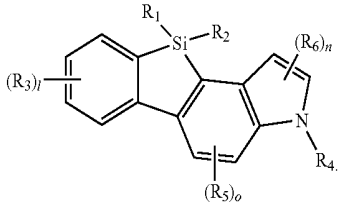
Formula 5



Formula 6



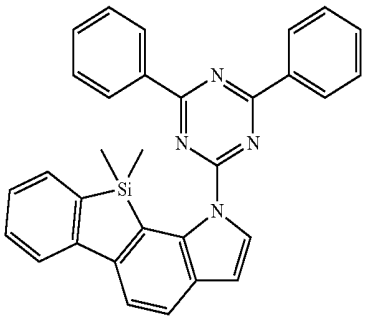
Formula 7



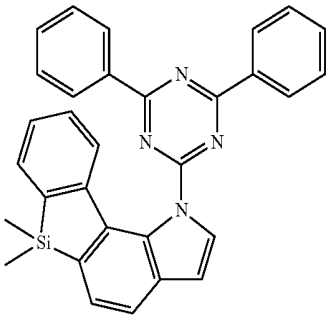
[0052] In Formulae 2 to 7, the substituents R_1 to R_6 and symbols n and I may each be the same as described above in connection with Formulae 1 and 1-1, and o may be an integer selected from 0 to 2.

[0053] In some embodiments, the compound represented by Formula 1 may be selected from the following compounds, but embodiments of the present disclosure are not limited thereto:

1



2



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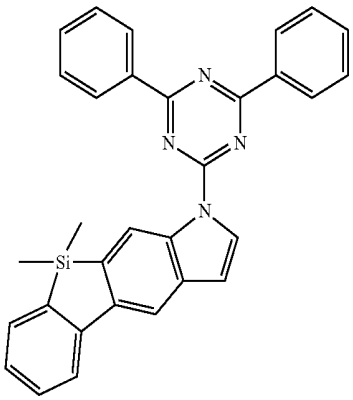

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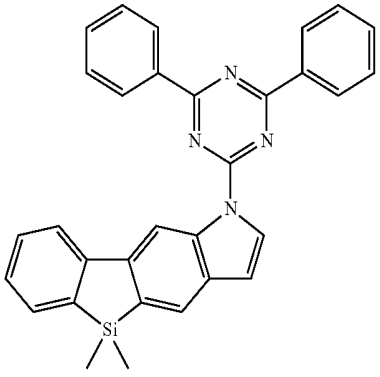

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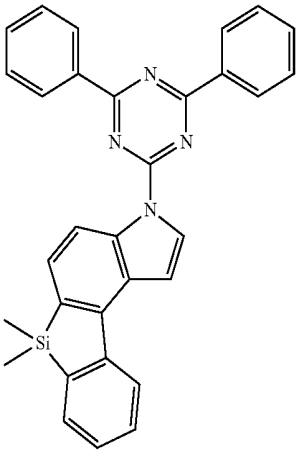
5



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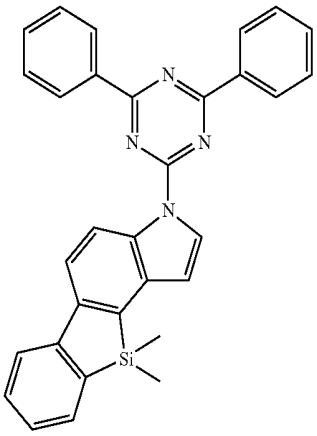
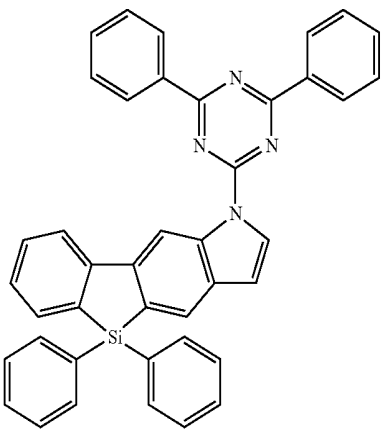


7



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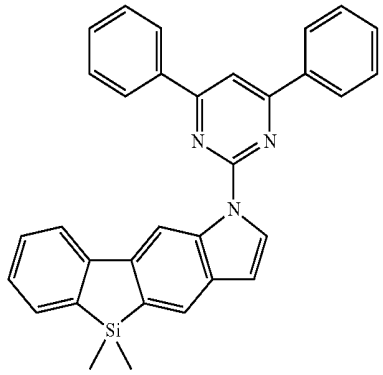
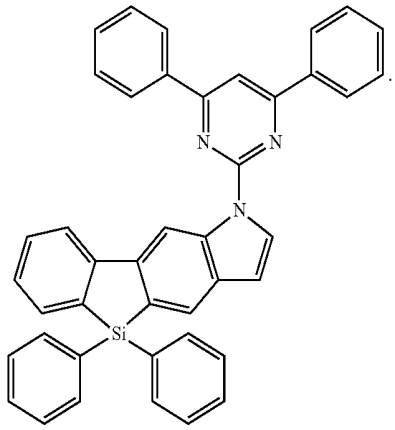
8



9



[0054] The term "organic layer" as used herein may refer to a single layer and/or a plurality of layers between the first electrode and the second electrode of an organic light-emitting device. The organic layer may include other materials besides an organic material.

[0055] The drawing is a schematic view of an organic light-emitting device **10** according to one or more embodiments of the present disclosure. The organic light-emitting device **10** includes a first electrode **110**, an organic layer **150**, and a second electrode **190**.

[0056] Hereinafter, the structure of an organic light-emitting device according to one or more embodiments of the present disclosure and a method of manufacturing an organic light-emitting device according to one or more embodiments of the present disclosure will be described in connection with the drawing.

[0057] In the drawing, a substrate may be under the first electrode **110** and/or above the second electrode **190**. The substrate may be a glass substrate and/or a transparent plastic substrate, each having excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and/or water-resistance.

[0058] The first electrode **110** may be formed by depositing and/or sputtering a suitable material for forming the first electrode **110** on the substrate. When the first electrode **110** is an anode, the material for the first electrode **110** may be selected from materials with a high work function in order to facilitate hole injection. The first electrode **110** may be a reflective electrode and/or a transmissive electrode. The material for the first electrode **110** may be a transparent and highly conductive material, and non-limiting examples of such a material may include indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO_2), and zinc oxide (ZnO). When the first electrode **110** is a semi-transmissive electrode and/or a reflective electrode, at least one selected from magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), and magnesium-silver (Mg—Ag) may be used as a material for forming the first electrode **110**.

[0059] The first electrode **110** may have a single-layer structure, and/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 the structure of the first electrode **110** is not limited thereto.

[0060] The organic layer **150** is on the first electrode **110**. The organic layer **150** may include an emitting layer.

[0061] The organic layer **150** may further include a hole transport region between the first electrode and the emitting layer, and an electron transport region between the emitting layer and the second electrode.

[0062] In some embodiments, the hole transport region may include at least one selected from a hole transport layer (HTL), a hole injection layer (HIL), a buffer layer, and an electron blocking layer, and the electron transport region may include at least one selected from a hole blocking layer (HBL), an electron transport layer (ETL), and an electron injection layer (EIL). However, embodiments of the present disclosure are not limited thereto.

[0063] The hole transport region may have a single-layered structure formed of a single material, a single-layered structure formed of a plurality of different materials, and/or a multi-layered structure having a plurality of layers formed of a plurality of different materials.

[0064] For example, the hole transport region may have a single-layered structure formed of a plurality of different materials, a structure of hole injection layer/hole transport layer, a structure of hole injection layer/hole transport layer/buffer layer, a structure of hole injection layer/buffer layer, a structure of hole transport layer/buffer layer, and/or a structure of hole injection layer/hole transport layer/electron blocking layer, wherein layers of each structure are sequentially stacked from the first electrode **110** in each stated order, but embodiments of the present disclosure are not limited thereto.

[0065] When the hole transport region includes a hole injection layer, the hole injection layer may be formed on the first electrode **110** using one or more suitable methods selected from vacuum deposition, spin coating, casting, a Langmuir-Blodgett (LB) method, ink-jet printing, laser-printing, and laser-induced thermal imaging.

[0066] When a hole injection layer is formed by vacuum deposition, the vacuum deposition may be performed at a deposition temperature of about 100° C. to about 500° C., at a vacuum degree of about 10^{-8} to about 10^{-3} torr, and at a deposition rate of about 0.01 Å/sec to about 100 Å/sec, depending on the compound to be deposited in the hole injection layer, and the structure of a hole injection layer to be formed.

[0067] When a hole injection layer is formed by spin coating, the spin coating may be performed at a coating rate of about 2,000 rpm to about 5,000 rpm, and at a temperature of about 80° C. to 200° C., depending on the compound to be deposited in the hole injection layer, and the structure of a hole injection layer to be formed.

[0068] When the hole transport region includes a hole transport layer, the hole transport layer may be formed on

the first electrode **110** and/or on the hole injection layer using one or more suitable methods selected from vacuum deposition, spin coating, casting, an LB method, ink-jet printing, laser-printing, and laser-induced thermal imaging. When the hole transport layer is formed by vacuum deposition and/or spin coating, the deposition and/or coating conditions for the hole transport layer may be similar to the deposition and coating conditions used for forming the hole injection layer.

[0069] The hole transport region may include at least one selected from m-MTDATA, TDATA, 2-TNATA, NPB, β-NPB, TPD, Spiro-TPD, Spiro-NPB, α-NPB, TAPC, HMTPD, 4,4',4"-tris(N-carbazolyl)triphenylamine (TCTA), polyaniline/dodecylbenzenesulfonic acid (PANI/DBSA), poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate) (PEDOT/PSS), polyaniline/camphor sulfonic acid (PANI/CSA), polyaniline/poly(4-styrenesulfonate) (PANI/PSS), a compound represented by Formula 201, and a compound represented by Formula 202:

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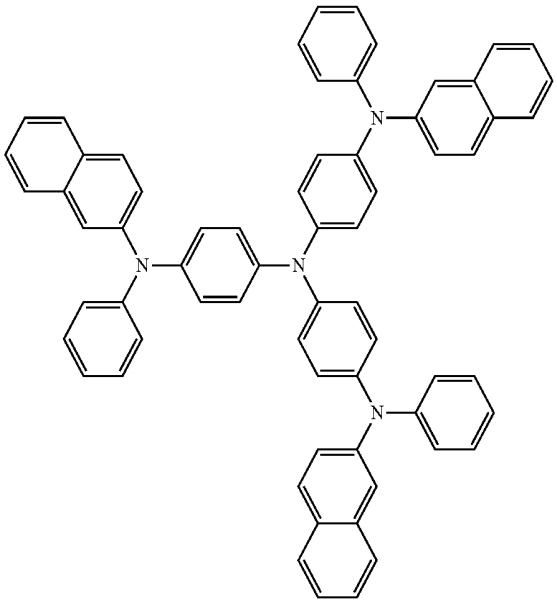
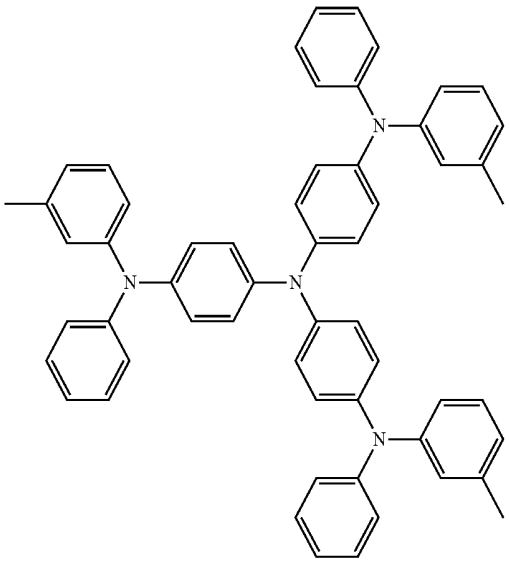
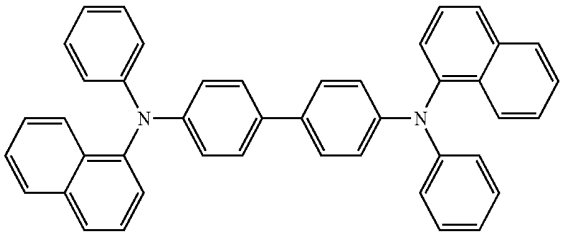


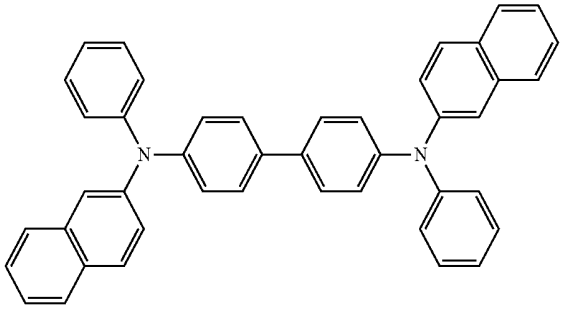
2-TNATA



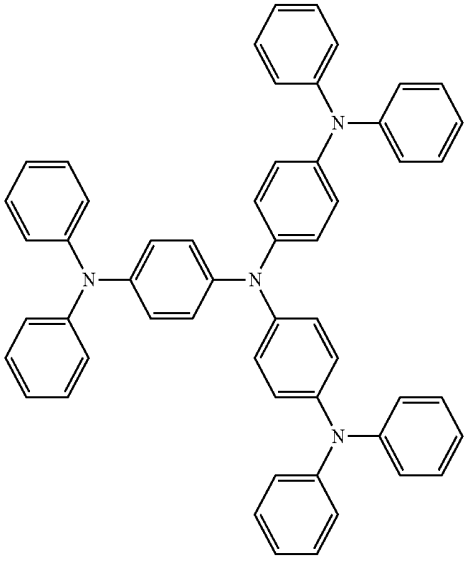
m-MTDATA



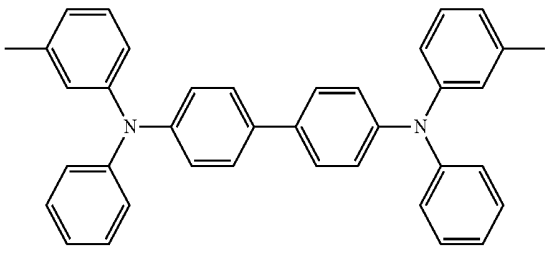
NPB



β-NPB



TDATA



TPD

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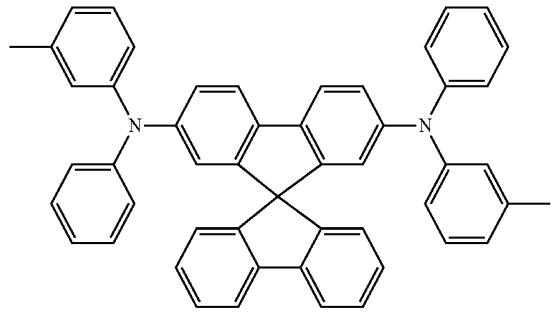
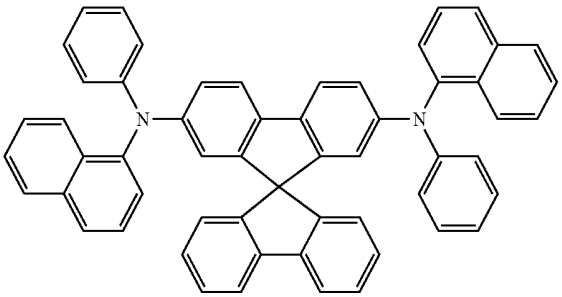
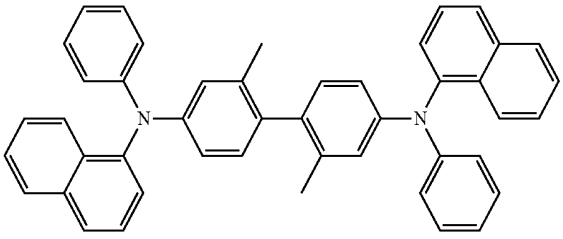


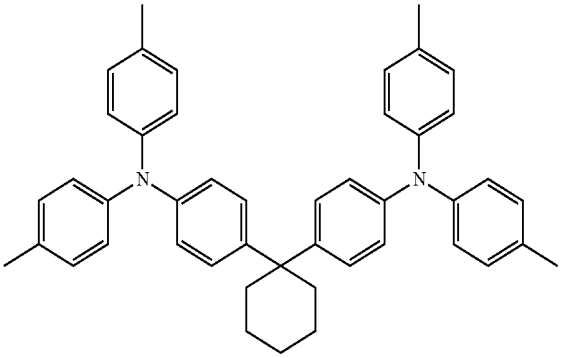
Spiro-TPD



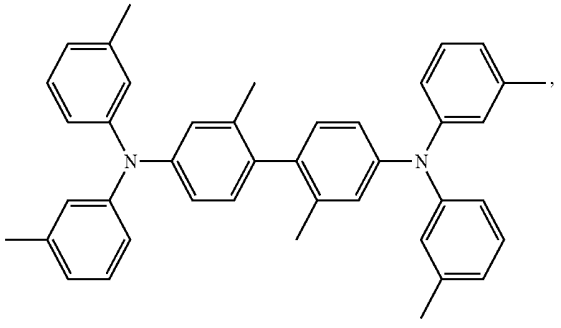
Spiro-NPB



α-NPB



TAPC



HMTPD

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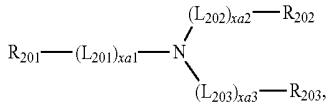
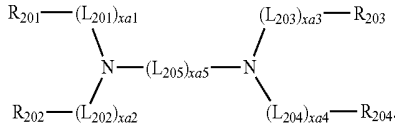
Formula 201



Formula 202



[0070] In Formulae 201 and 202,

[0071] L_{201} to L_{205} 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;

[0072] xa1 to xa4 may each independently be selected from 0, 1, 2, and 3;

[0073] xa5 may be selected from 1, 2, 3, 4, and 5; and

[0074] R_{201} to R_{204} may each independently be selected from a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_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.

[0075] In some embodiments, in Formulae 201 and 202,

[0076] L_{201} to L_{205} may each independently be selected from the group consisting of:

[0077] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorene group, a dibenzofluorene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, a chrysenylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a quinolinylene group, an isoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a carbazolylene group, and a triazinylene group; and

[0078] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorene group, a dibenzofluorene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, a chrysenylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a quinolinylene group, an isoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a carbazolylene group, and a triazinylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl

group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

[0079] xa1 to xa4 may each independently be selected from 0, 1, and 2;

[0080] xa5 may be selected from 1, 2, and 3;

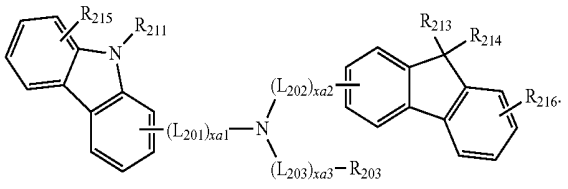
[0081] R_{201} to R_{204} may each independently be selected from the group consisting of:

[0082] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

[0083] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, an azulenyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, but embodiments of the present disclosure are not limited thereto.

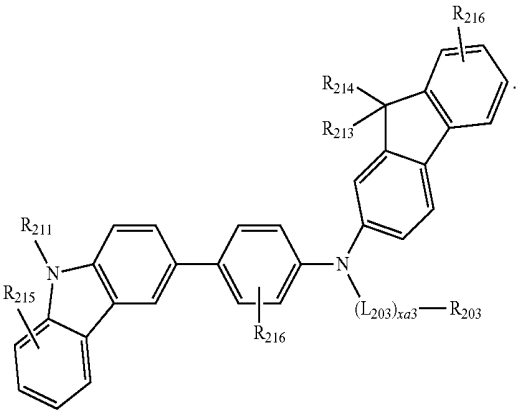
[0084] The compound represented by Formula 201 may be further represented by Formula 201A:

Formula 201A



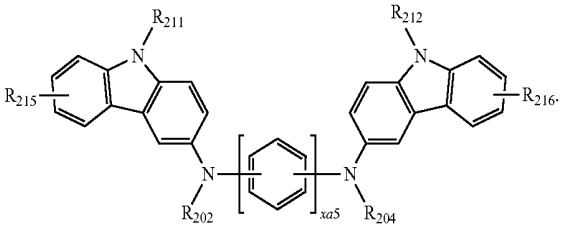
[0085] For example, the compound represented by Formula 201 may be further represented by Formula 201A-1, but embodiments of the present disclosure are not limited thereto:

Formula 201A-1



[0086] The compound represented by Formula 202 may be further represented by Formula 202A, but embodiments of the present disclosure are not limited thereto:

Formula 202A



[0087] L_{201} to L_{203}, xa1 to xa3, xa5, and R_{202} to R_{204} in Formulae 201A, 201A-1, and 202A may each be the same as described herein in connection with Formulae 201 and 202, R_{211} and R_{212} may each be the same as described herein in connection with R_{203}, and R_{213} to R_{216} may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{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, and a monovalent non-aromatic condensed heteropolycyclic group.

[0088] For example, in Formulae 201A, 201A-1, and 202A,

[0089] L_{201} to L_{203} may each independently be selected from the group consisting of:

[0090] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, a chrysenylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a quinolinylene group, an isoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a carbazolylene group, and a triazinylene group; and

[0091] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, a chrysenylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a quinolinylene group, an isoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a carbazolylene group, and a triazinylene group, each substituted with at least one selected ftom deuterium. —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

[0092] xa1 to xa3 may each independently be selected from 0 and 1;

[0093] R_{203}, R_{211}, and R_{212} may each independently be selected from the group consisting of:

[0094] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyi group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

[0095] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyi group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

[0096] R_{213} and R_{214} may each independently be selected from the group consisting of:

[0097] a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group;

[0098] a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

[0099] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

[0100] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

[0101] R_{215} and R_{216} may each independently be selected from the group consisting of:

[0102] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, and a C_1-C_{20} alkoxy group;

[0103] a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

[0104] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, and a triazinyl group; and

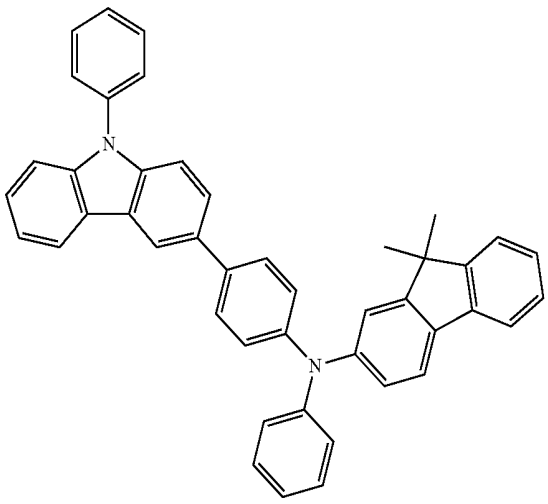
[0105] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

[0106] xa5 may be selected from 1 and 2.

[0107] R_{213} and R_{214} in Formulae 201A and 201A-1 may be linked (e.g., coupled) to each other to form a saturated or unsaturated ring.

[0108] The compound represented by Formula 201 and the compound represented by Formula 202 may be selected from compounds HT1 to HT20, but embodiments of the present disclosure are not limited thereto:

HT1



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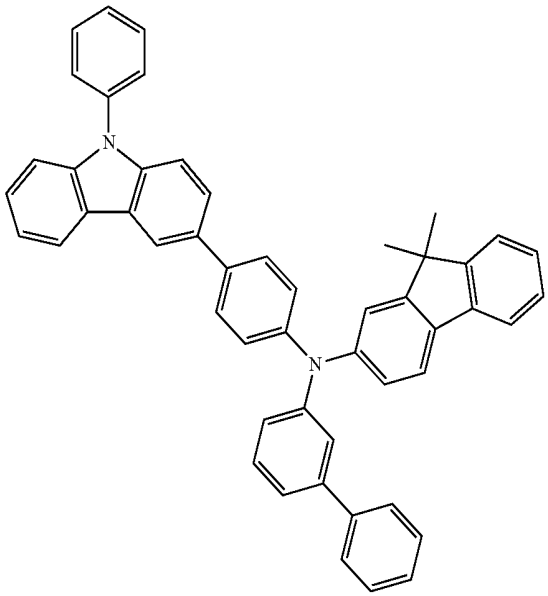
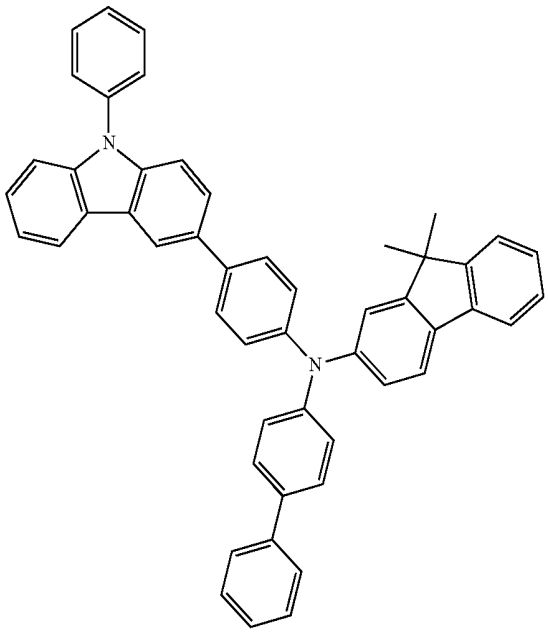
HT2



HT3



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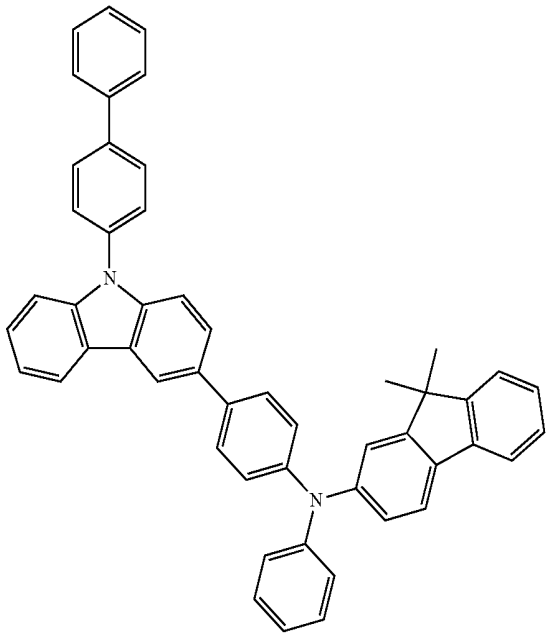
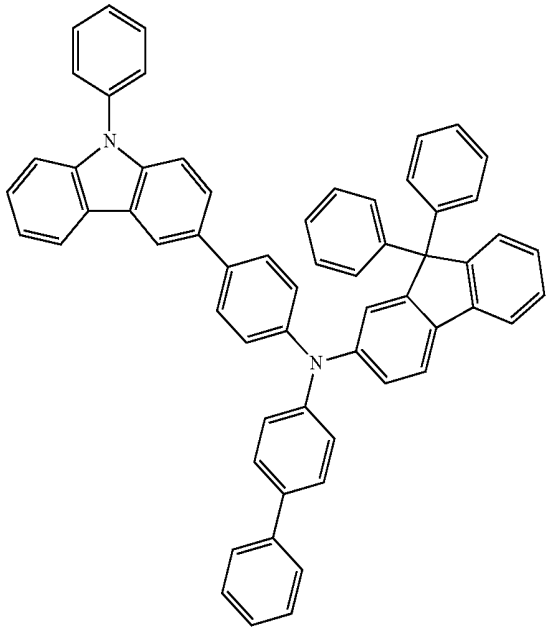
HT4



HT5



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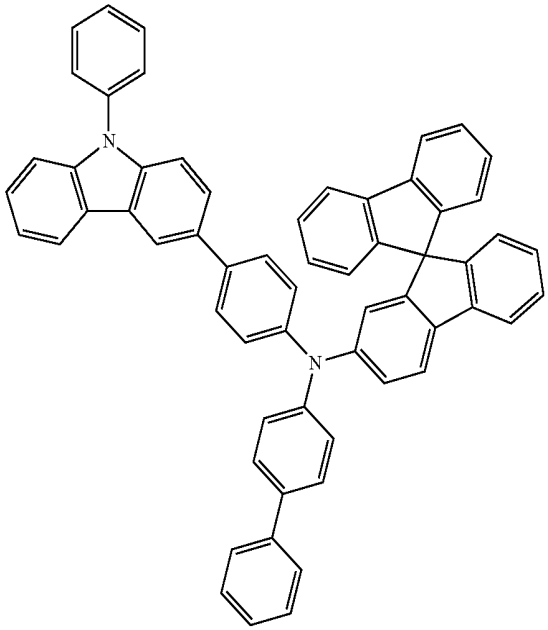
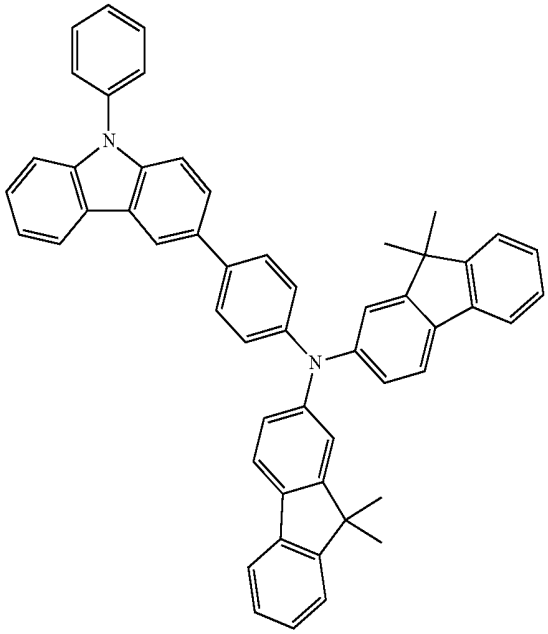
HT6



HT7



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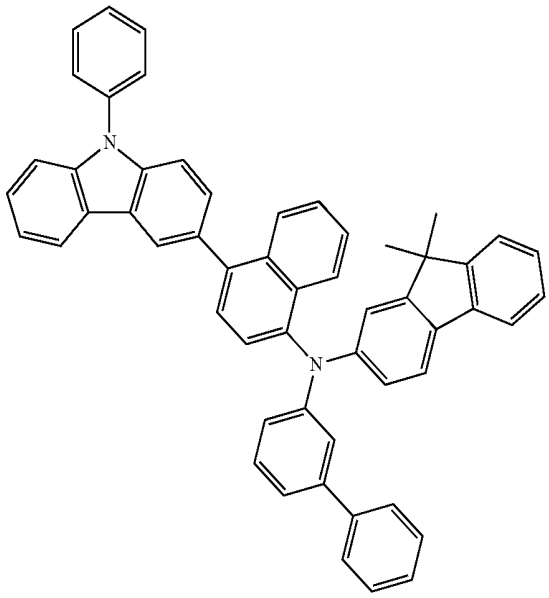
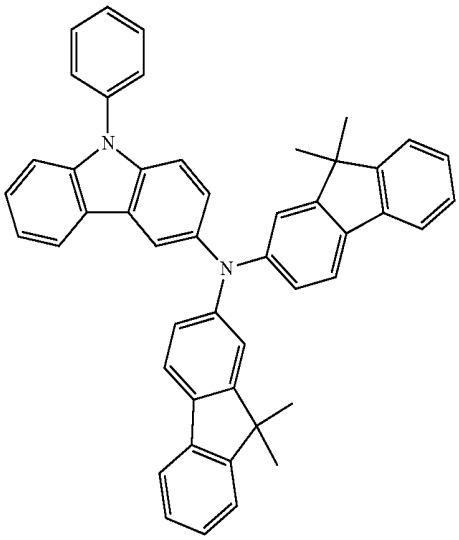
HT8



HT9



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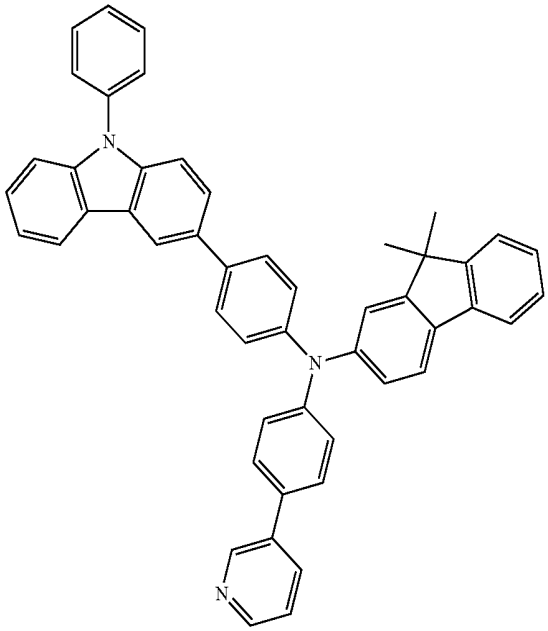
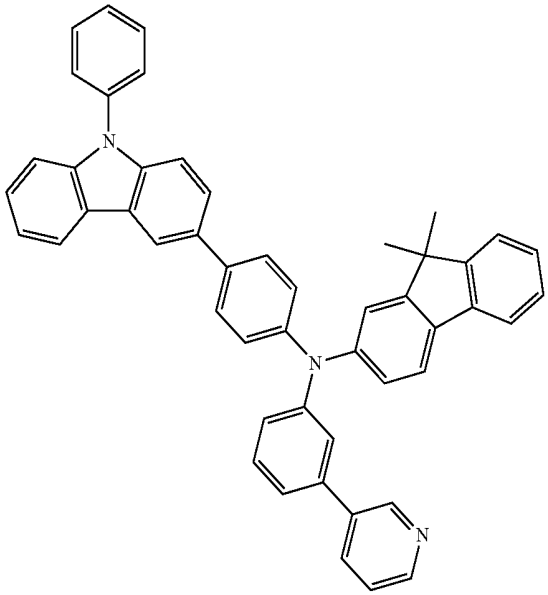
HT10



HT11



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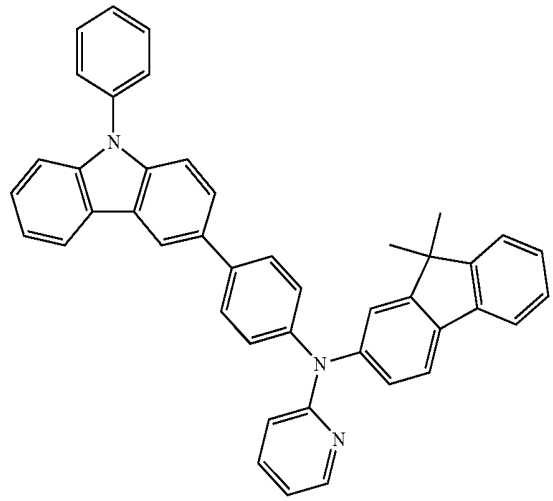
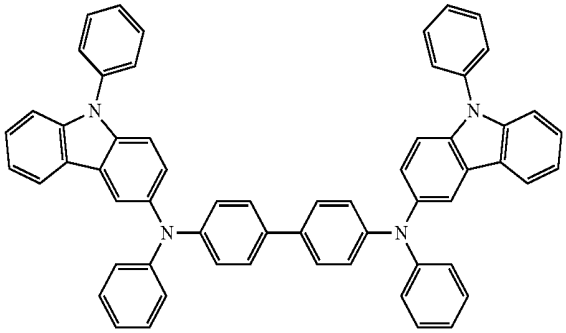
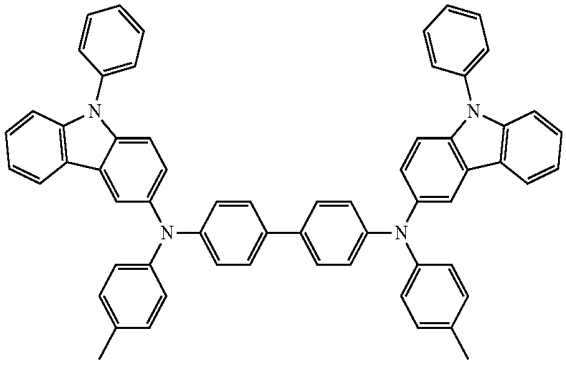
HT12



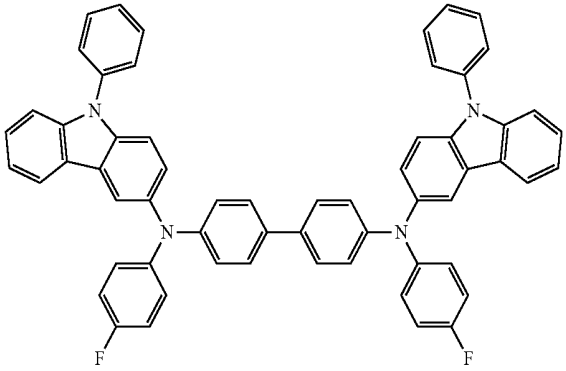
HT13



HT14



HT15



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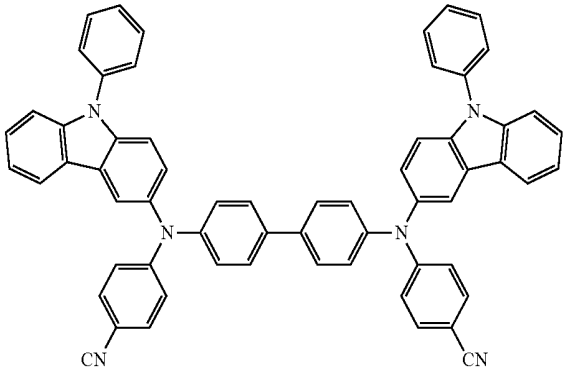
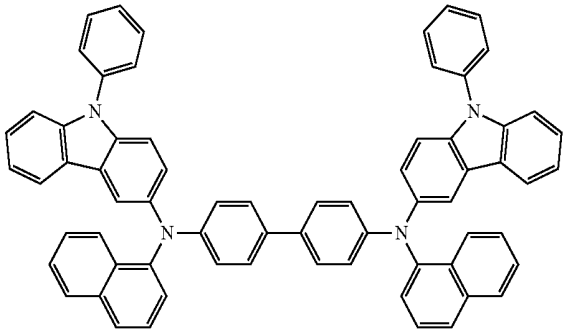
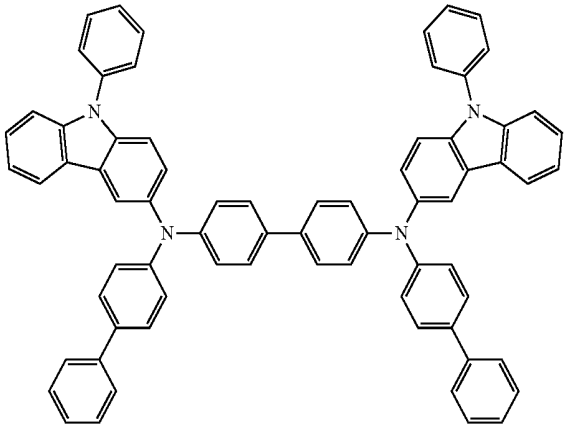
HT16



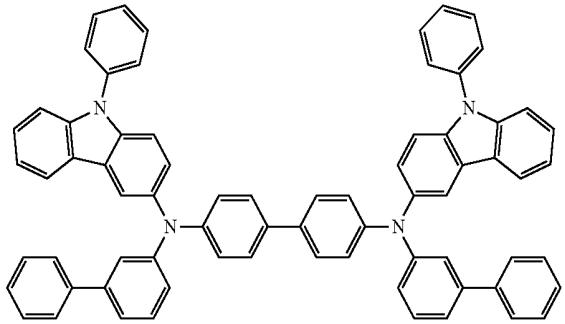
HT17



HT18



HT19



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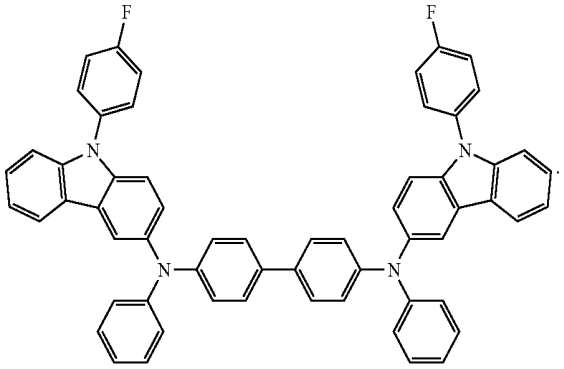
HT20

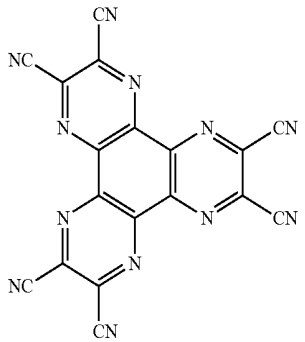


[0109] The thickness of the hole transport region may be about 100 Å to about 10,000 Å, and in some embodiments, about 100 Å to about 1,000 Å. When the hole transport region includes a hole injection layer and a hole transport layer, the thickness of the hole injection layer may be about 100 Å to about 10,000 Å, and in some embodiments, about 100 Å to about 1,000 Å. The thickness of the hole transport layer may be about 50 Å to about 2,000 Å, and in some embodiments, about 100 Å to about 1,500 Å. When the thicknesses of the hole transport region, the hole injection layer, and the hole transport layer are each within these ranges, satisfactory hole transport characteristics may be obtained without a substantial increase in driving voltage.

[0110] 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 and/or non-homogeneously dispersed in the hole transport region.

[0111] The charge-generation material may be, for example, a p-dopant. The p-dopant may be selected from a quinone derivative, a metal oxide, and a cyano group-containing compound, but embodiments of the present disclosure are not limited thereto. Non-limiting examples of the p-dopant may include quinone derivatives (such as tetracyanoquinonedimethane (TCNQ) and/or 2,3,5,6-tetrafluoro-tetracyano-1,4-benzoquinonedimethane (F4-TCNQ)), metal oxides (such as a tungsten oxide and/or a molybdenum oxide), and Compound HT-D1, but embodiments of the present disclosure are not limited thereto:

Compound HT-D1



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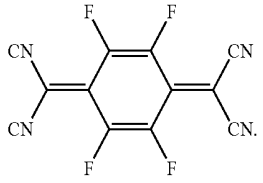
F4-TCNQ



[0112] The hole transport region may further include a buffer layer in addition to an electron blocking layer, a hole injection layer, and a hole transport layer. Since the buffer layer may compensate for an optical resonance distance according to a wavelength of light emitted from the emitting layer (e.g., be used to adjust the optical resonance distance to match the wavelength of light emitted from the emitting layer), the light-emission efficiency of the resulting organic light-emitting device may be improved. Materials that are included in the hole transport region may be used in the buffer layer. In some embodiments, the electron blocking layer prevents or reduces injection of electrons from the electron transport region.

[0113] An emitting layer may be formed on the first electrode **110** and/or on the hole transport region using one or more suitable methods selected from vacuum deposition, spin coating, casting, an LB method, ink-jet printing, laser-printing, and laser-induced thermal imaging. When an emitting layer is formed by vacuum deposition and/or spin coating, the deposition and coating conditions used for the emitting layer may be similar to those used for the hole injection layer.

[0114] When the organic light-emitting device **10** is a full color organic light-emitting device, the emitting layer may be patterned into a red emitting layer, a green emitting layer, or a blue emitting layer, according to a sub pixel. In some embodiments, the emitting layer may have a stacked structure of a red emitting layer, a green emitting layer, and a blue emitting layer, and/or may include a red-light emission material, a green-light emission material, and a blue-light emission material, which are mixed with each other in a single layer to thereby emit white light.

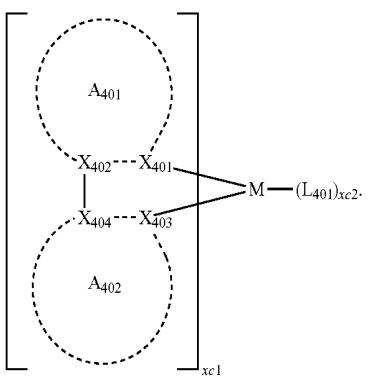
[0115] The emitting layer may include a host and a dopant.

[0116] The host may include the compound of Formula 1.

[0117] The dopant may include a suitable fluorescent dopant and/or a suitable phosphorescent dopant.

[0118] The phosphorescent dopant may include an organometallic complex represented by Formula 401:

Formula 401



[0119] In Formula 401,

[0120] M may be selected from iridium (Ir), platinum (Pt), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), and thulium (Tm);

[0121] X_{401} to X_{404} may each independently be selected from nitrogen (N) and carbon (C);

[0122] rings A_{401} and A_{402} may each independently be selected from a substituted or unsubstituted benzene, a substituted or unsubstituted naphthalene, a substituted or unsubstituted fluorenene, a substituted or unsubstituted spiro-fluorenene, a substituted or unsubstituted indene, a substituted or unsubstituted pyrrole, a substituted or unsubstituted thiophene, a substituted or unsubstituted furan, a substituted or unsubstituted imidazole, a substituted or unsubstituted pyrazole, a substituted or unsubstituted thiazole, a substituted or unsubstituted isothiazole, a substituted or unsubstituted oxazole, a substituted or unsubstituted isoxazole, a substituted or unsubstituted pyridine, a substituted or unsubstituted pyrazine, a substituted or unsubstituted pyrimidine, a substituted or unsubstituted pyridazine, a substituted or unsubstituted quinoline, a substituted or unsubstituted isoquinoline, a substituted or unsubstituted benzoquinoline, a substituted or unsubstituted quinoxaline, a substituted or unsubstituted quinazoline, a substituted or unsubstituted carbazole, a substituted or unsubstituted benzimidazole, a substituted or unsubstituted benzofuran, a substituted or unsubstituted benzothiophene, a substituted or unsubstituted isobenzothiophene, a substituted or unsubstituted benzoxazole, a substituted or unsubstituted isobenzoxazole, a substituted or unsubstituted triazole, a substituted or unsubstituted oxadiazole, a substituted or unsubstituted triazine, a substituted or unsubstituted dibenzofuran, and a substituted or unsubstituted dibenzothiophene; and

[0123] at least one substituent of the substituted benzene, substituted naphthalene, substituted fluorenene, substituted spiro-fluorenene, substituted indene, substituted pyrrole, substituted thiophene, substituted furan, substituted imidazole, substituted pyrazole, substituted thiazole, substituted isothiazole, substituted oxazole, substituted isoxazole, substituted pyridine, substituted pyrazine, substituted pyrimidine, substituted pyridazine, substituted quinoline, substituted isoquinoline, substituted benzoquinoline, substituted quinoxaline, substituted quinazoline, substituted carbazole, substituted benzimidazole, substituted benzofuran, substituted benzothiophene, substituted isobenzothiophene, substituted benzoxazole, substituted isobenzoxazole, substituted triazole, substituted oxadiazole, substituted triazine, substituted dibenzofuran, and substituted dibenzothiophene may be selected from the group consisting of:

[0124] 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;

[0125] 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, —$N(Q_{401})(Q_{402})$, —$Si(Q_{403})(Q_{404})(Q_{405})$, and —$B(Q_{406})(Q_{407})$,

[0126] 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, and a non-aromatic condensed polycyclic group;

[0127] 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, —$N(Q_{411})(Q_{412})$, —$Si(Q_{413})(Q_{414})(Q_{415})$ and —$B(Q_{416})(Q_{417})$; and

[0128] —$N(Q_{421})(Q_{422})$, —$Si(Q_{423})(Q_{424})(Q_{425})$ and —$B(Q_{426})(Q_{427})$),

[0129] L_{401} may be an organic ligand;

[0130] xc1 may be selected from 1, 2, and 3; and

[0131] xc2 may be selected from 0, 1, 2, and 3.

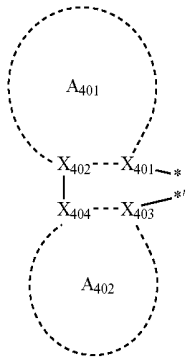
[0132] Q_{401} to Q_{407}, Q_{411} to Q_{417}, and Q_{421} to Q_{427} may each be the same as described herein in connection with Q_1.

[0133] L_{401} may be any suitable monovalent, divalent, and/or trivalent organic ligand. For example, L_{401} may be selected from a halogen ligand (for example, Cl and/or F), a diketone ligand (for example, acetylacetonate, 1,3-diphenyl-1,3-propandionate, 2,2,6,6-tetramethyl-3,5-heptandionate, and/or hexafluoroacetonate), a carboxylic acid ligand (for example, picolinate, dimethyl-3-pyrazolecarboxylate, and/or benzoate), a carbon monoxide ligand, an isonitrile ligand, a cyano ligand, and a phosphorous ligand (for example, phosphine and/or phosphite), but embodiments of the present disclosure are not limited thereto.

[0134] When A_{401} in Formula 401 has two or more substituents, the substituents of A_{401} may be linked (e.g., coupled) to each other to form a saturated or unsaturated ring.

[0135] When A_{402} in Formula 401 has two or more substituents, the substituents of A_{402} may be linked (e.g., coupled) to each other to form a saturated or unsaturated ring.

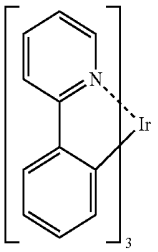
[0136] When xc1 in Formula 401 is two or more, a plurality of ligands



in Formula 401 may be identical to or different from each other. When xc1 in Formula 401 is two or more, A_{401} and A_{402} may each be directly connected (e.g., by a bond) and/or connected via a linking group (for example, a C_1-C_5 alkylene group, —N(R')— (wherein R' may be a C_1-C_{10} alkyl group and/or a C_6-C_{20} aryl group), and/or —C(=O)—) to another neighboring A_{401} and A_{402} ligand, respectively.

[0137] The phosphorescent dopant may include at least one selected from Compounds PD1 to PD74, but embodiments of the present disclosure are not limited thereto:

PD1



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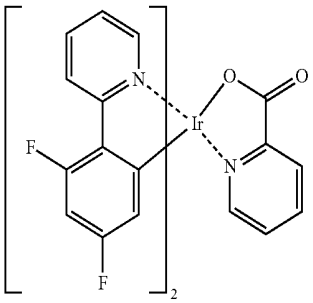

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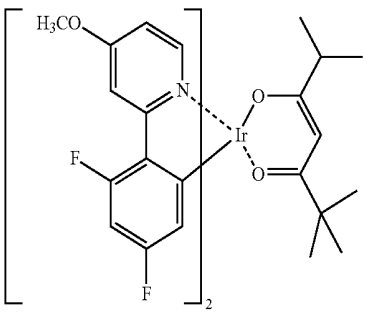

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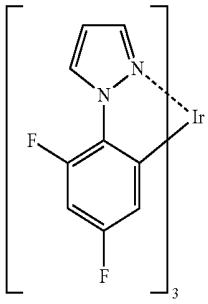

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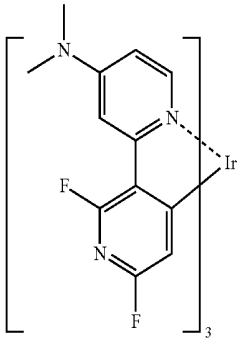

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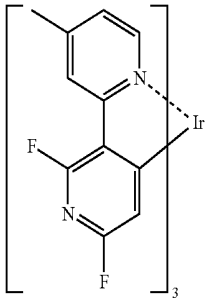

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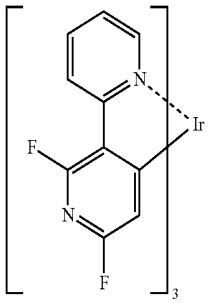

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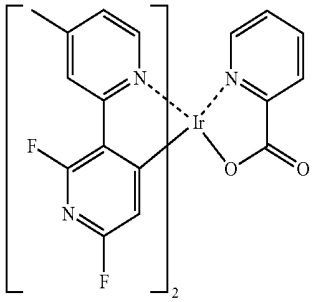

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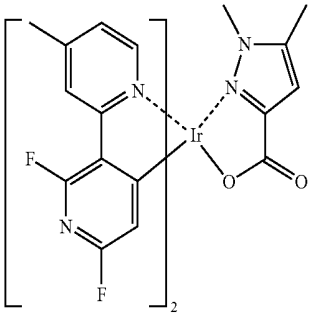

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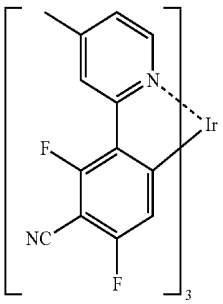

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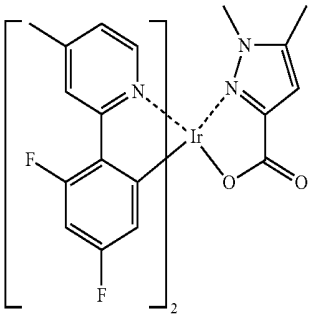

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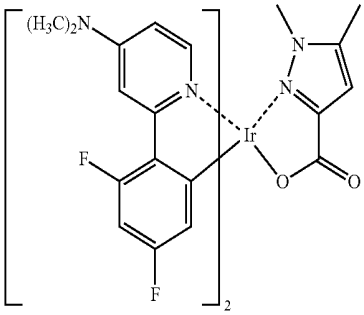

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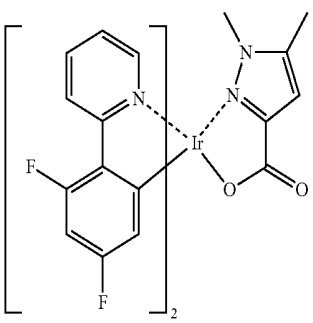

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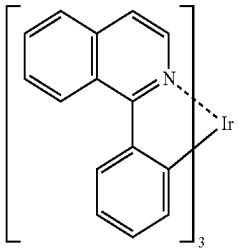

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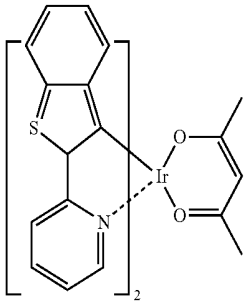

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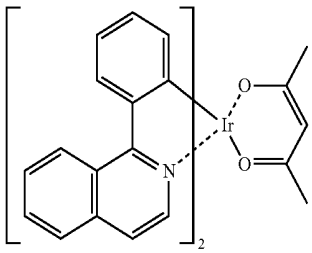

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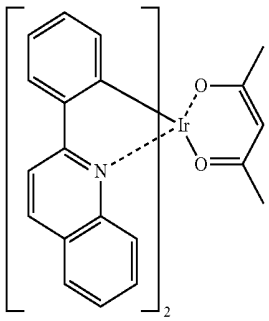

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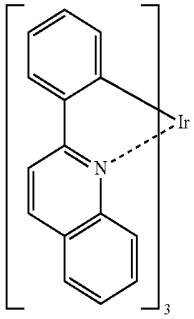

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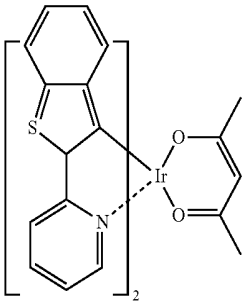

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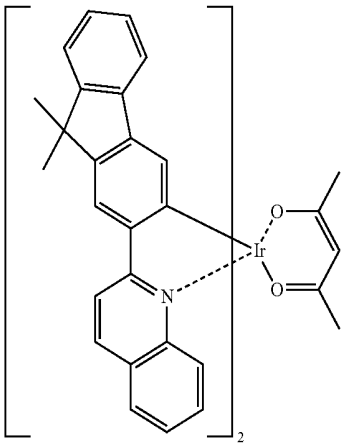

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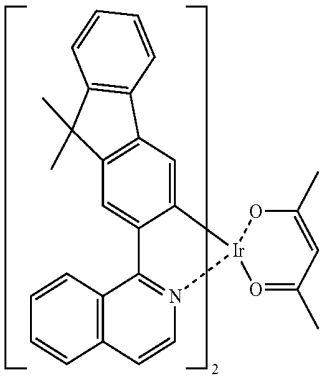

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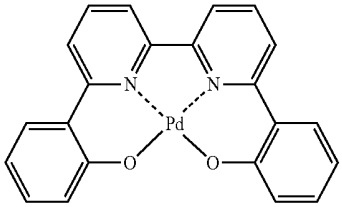

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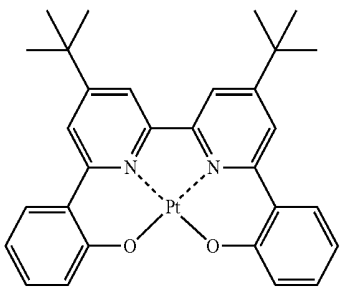

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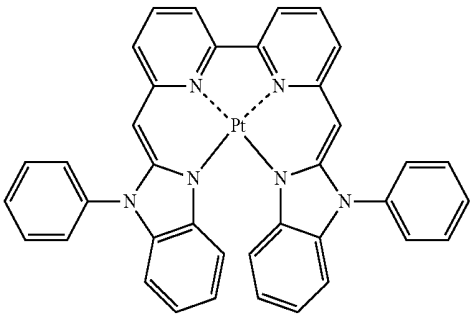

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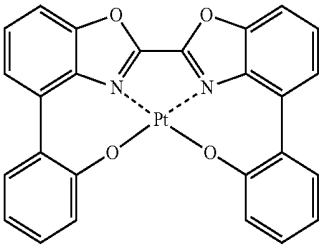

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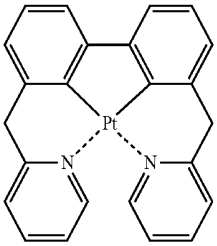

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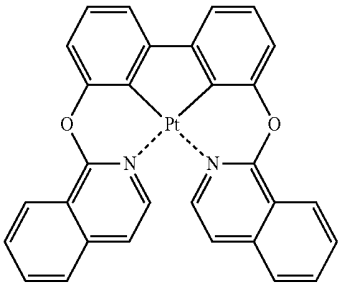

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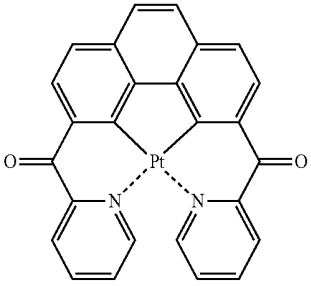

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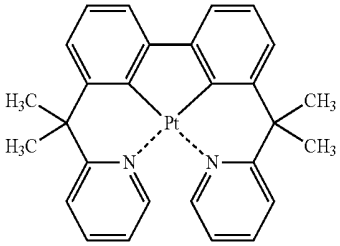

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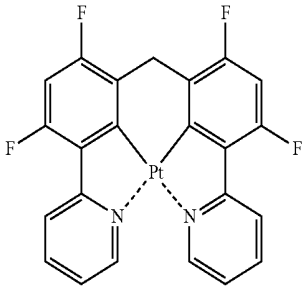

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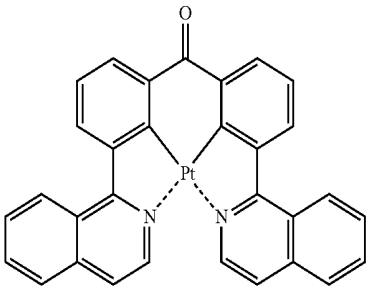

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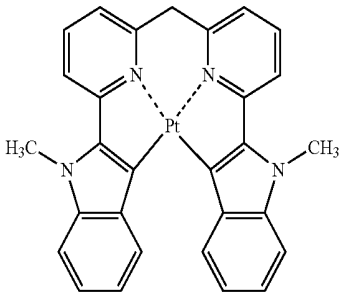

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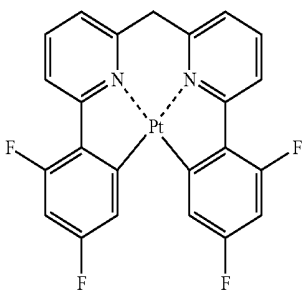

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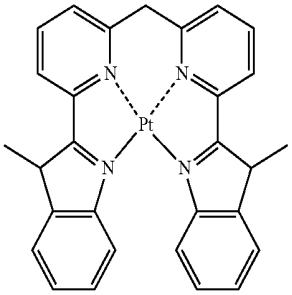

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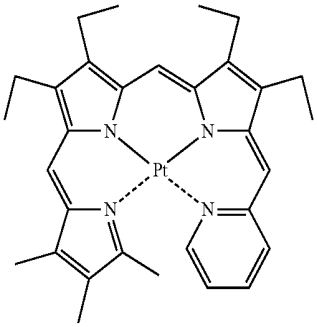

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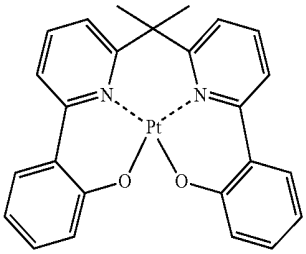

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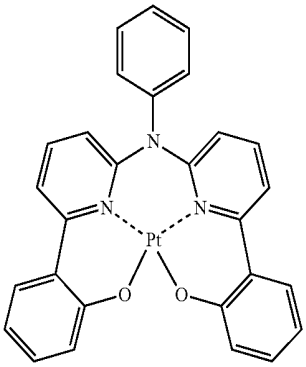

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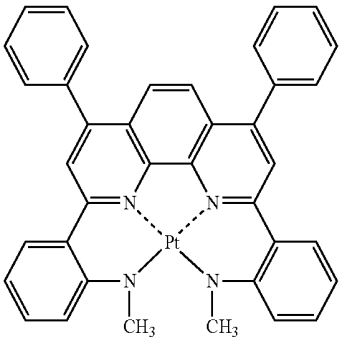

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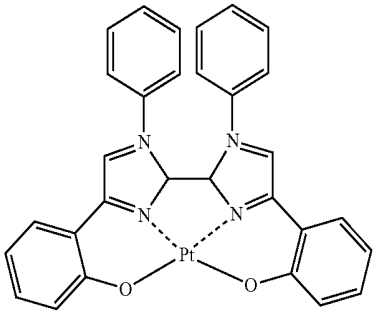

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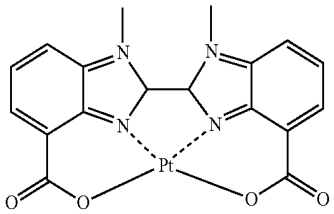

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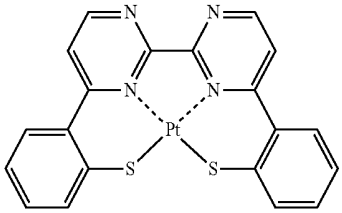
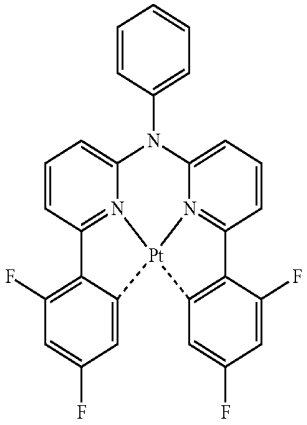


PD42



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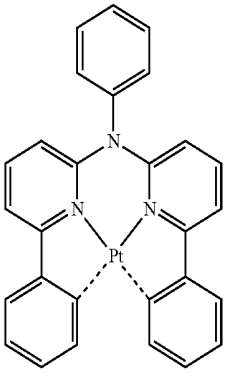

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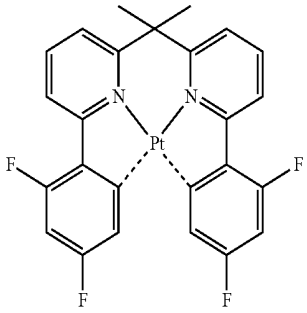

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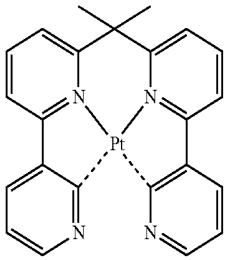

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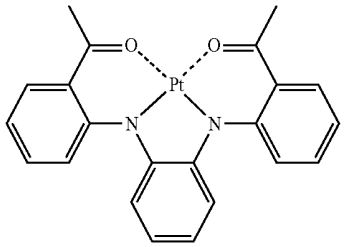

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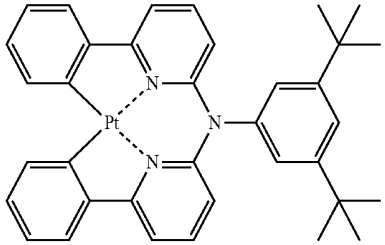

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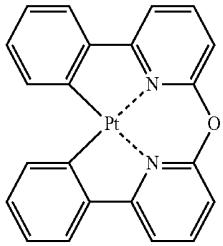

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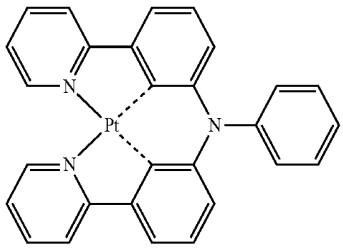

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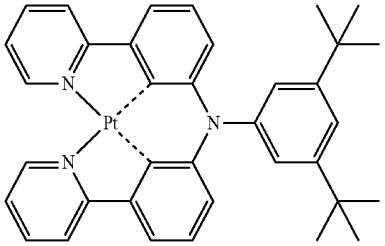

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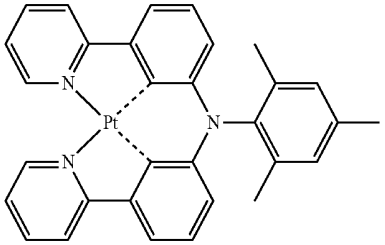

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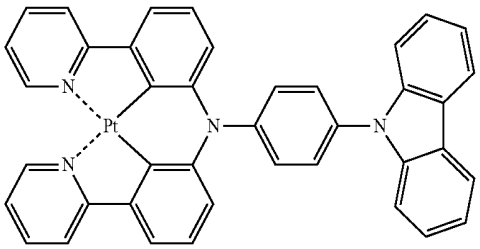

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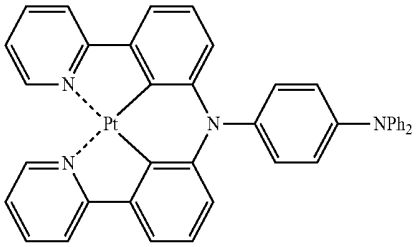

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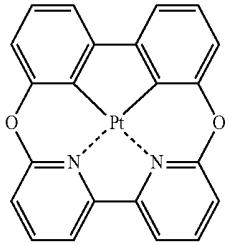

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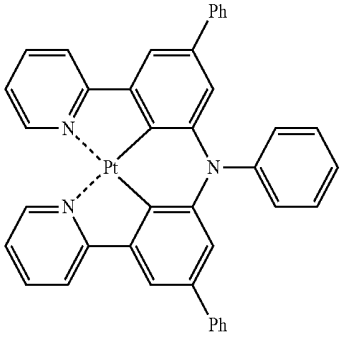

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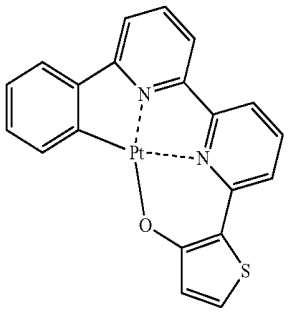

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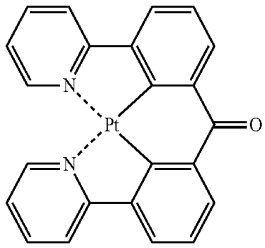

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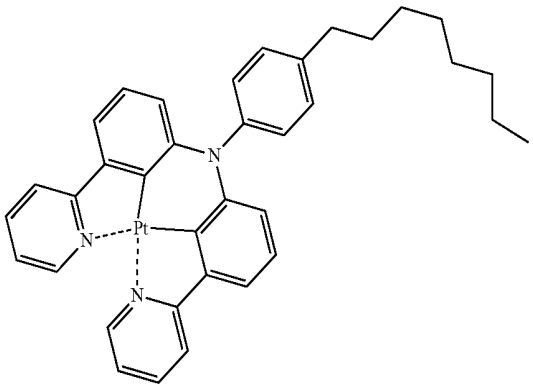

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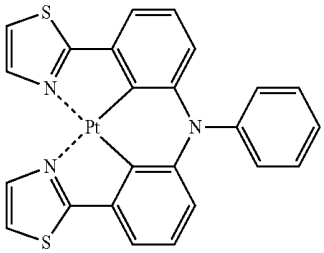

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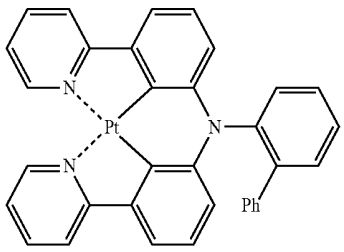

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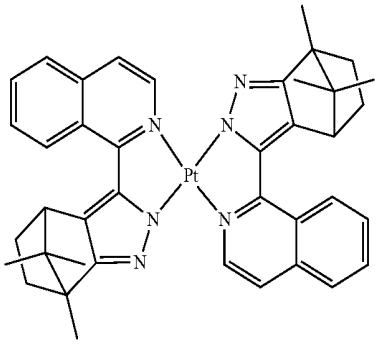

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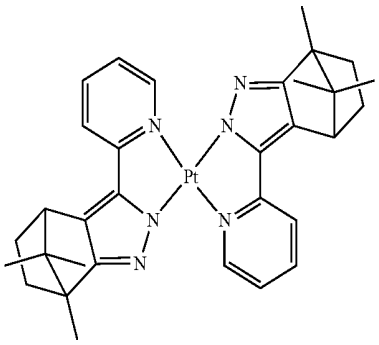

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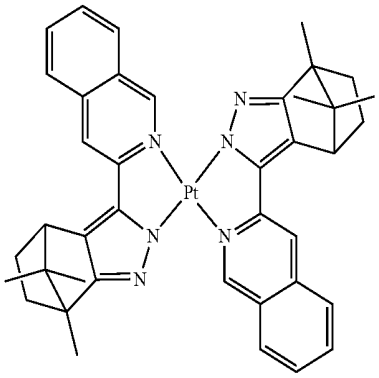

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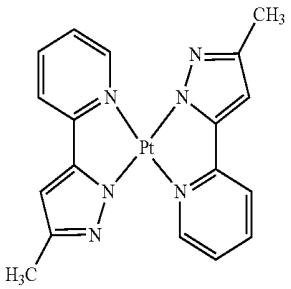
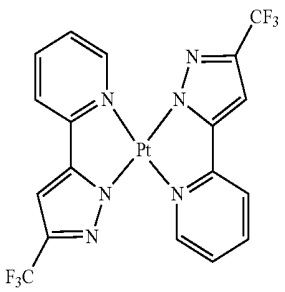


PD65



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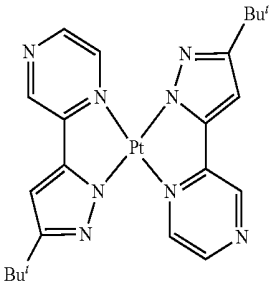
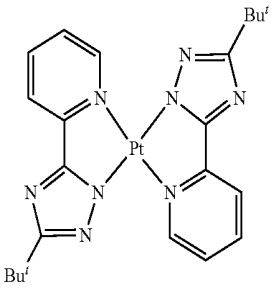
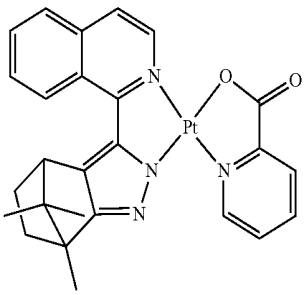
PD66



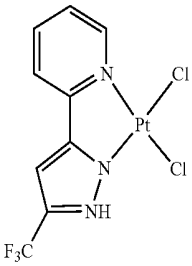
PD67



PD68



PD69



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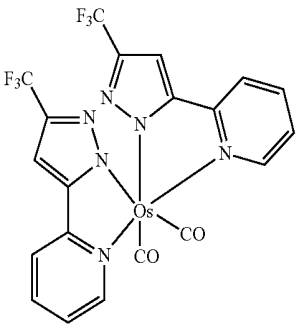

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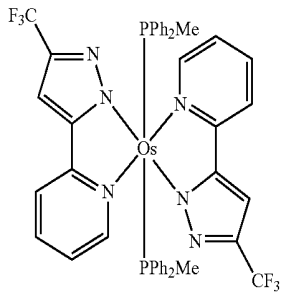
PD71



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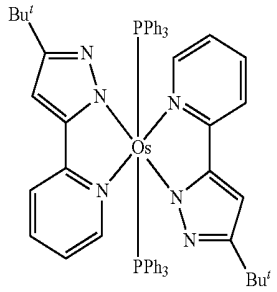
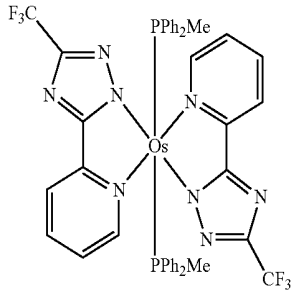


PD73



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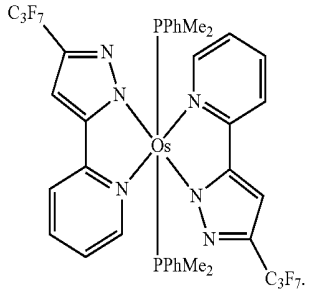
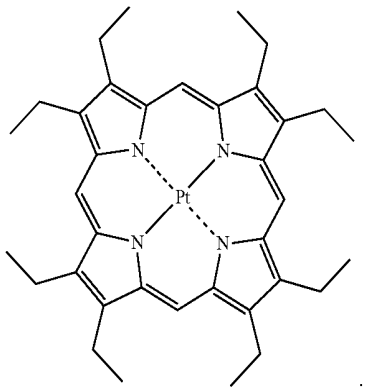
PD74

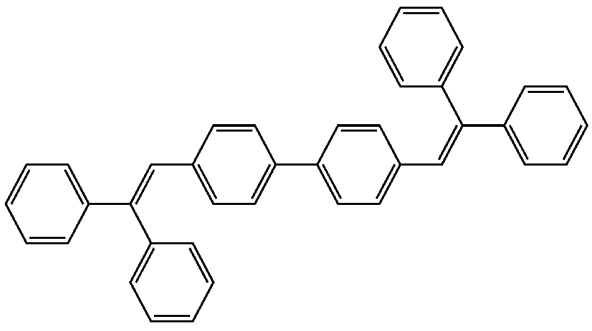


[0138] In some embodiments, the phosphorescent dopant may include PtOEP:

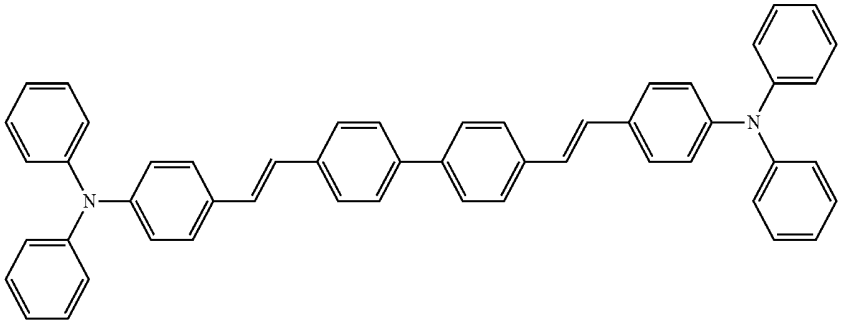


PtOEP

[0139] The fluorescent dopant may include at least one selected from DPVBi, DPAVBi, TBPe, DCM, DCJTB, Coumarin 6, and C545T:



DPVBi



DPAVBi

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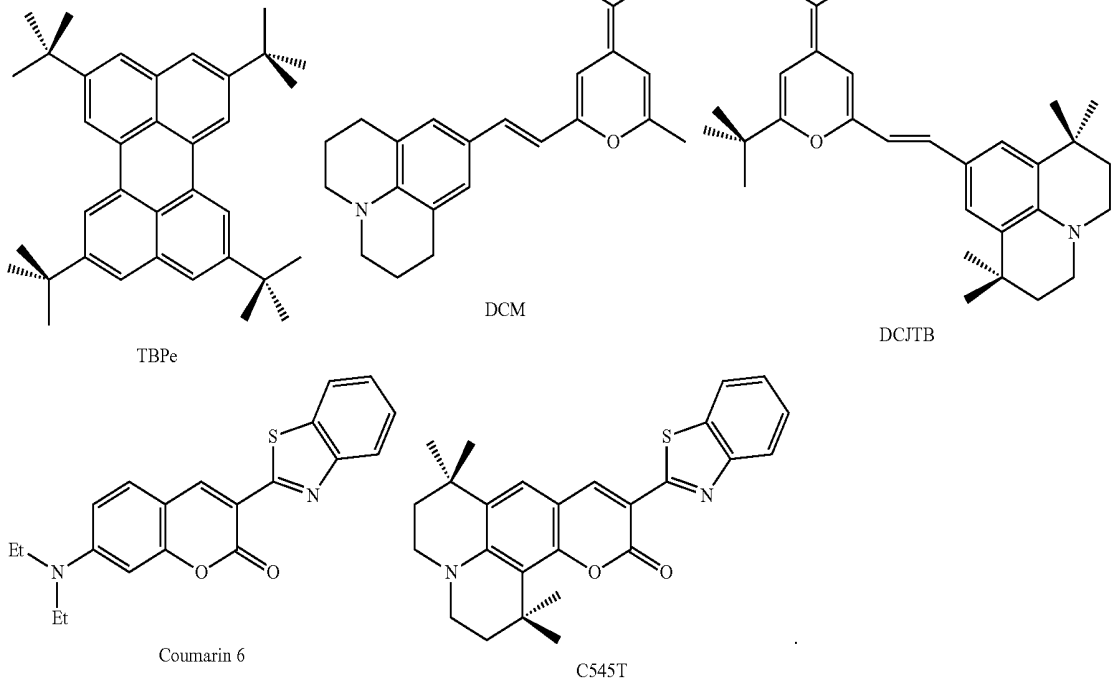
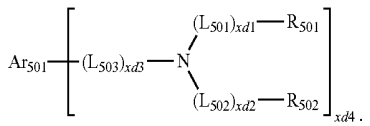


[0140] In some embodiments, the fluorescent dopant may include a compound represented by Formula 501:

Formula 501



[0141] In Formula 501,

[0142] Ar_{501} may be selected from the group consisting of:

[0143] a naphthalene, a heptalene, a fluorenene, a spiro-fluorene, a benzofluorene, a dibenzofluorene, a phenalene, a phenanthrene, an anthracene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a naphthacene, a picene, a perylene, a pentaphene, and an indenoanthracene; and

[0144] a naphthalene, a heptalene, a fluorenene, a spiro-fluorene, a benzofluorene, a dibenzofluorene, a phenalene, a phenanthrene, an anthracene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a naphthacene, a picene, a perylene, a pentaphene, and an indenoanthracene, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a 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, monovalent non-aromatic condensed heteropolycyclic group, and —$Si(Q_{501})(Q_{502})(Q_{503})$ (wherein Q_{501} to Q_{503} may be each independently selected from hydrogen, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_6-C_{60} aryl group, and a C_1-C_{60} heteroaryl group);

[0145] L_{501} to L_{503} may each be the same as described herein in connection with L_{203};

[0146] R_{501} and R_{502} may be each independently selected from the group consisting of:

[0147] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

[0148] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid

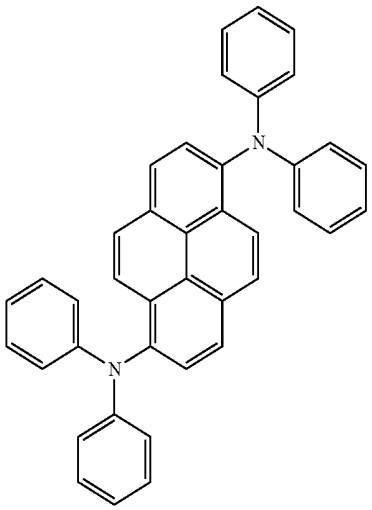
group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

[0149] xd1 to xd3 may each independently be selected from 0, 1, 2, and 3; and

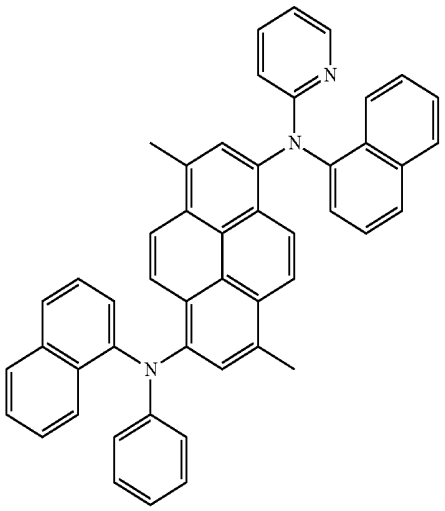
[0150] xd4 may be selected from 1, 2, 3, and 4.

[0151] The fluorescent dopant may include at least one selected from Compounds FD1 to FD8:

FD1



FD2



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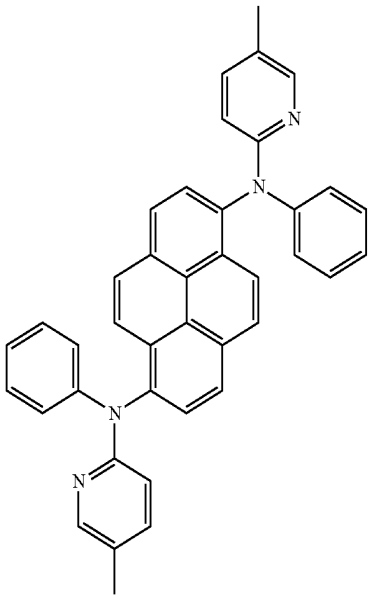
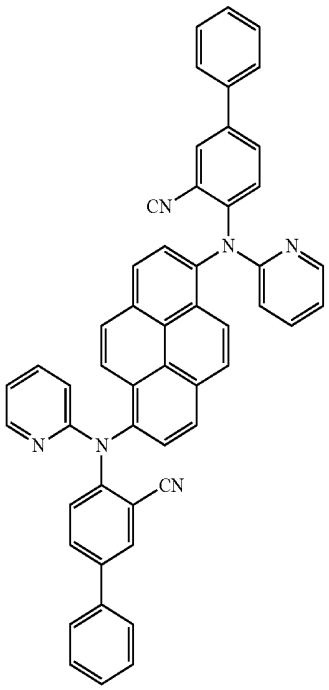
FD3



FD4



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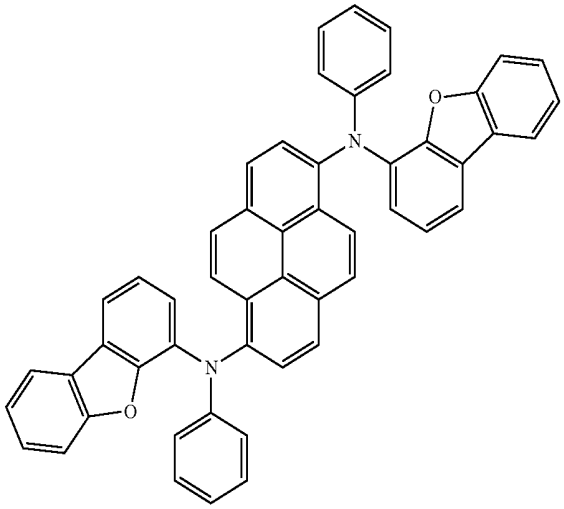
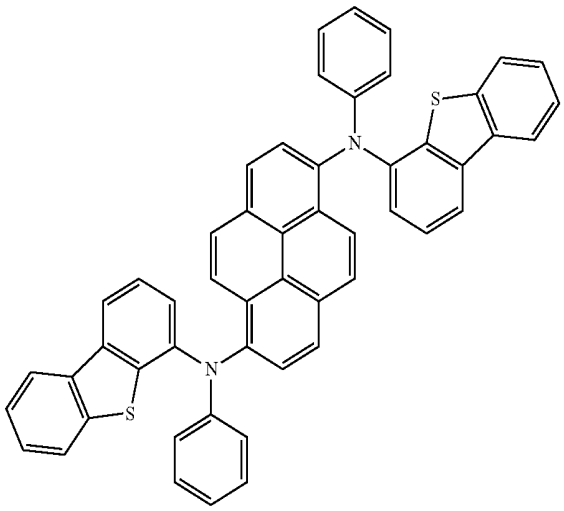
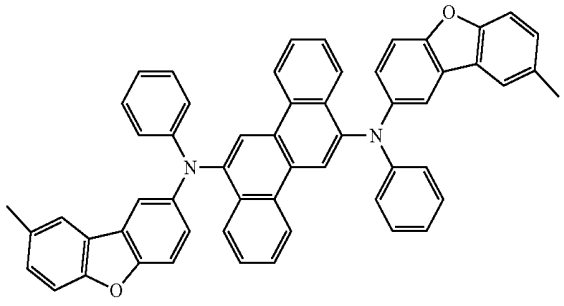
FD5



FD6



FD7



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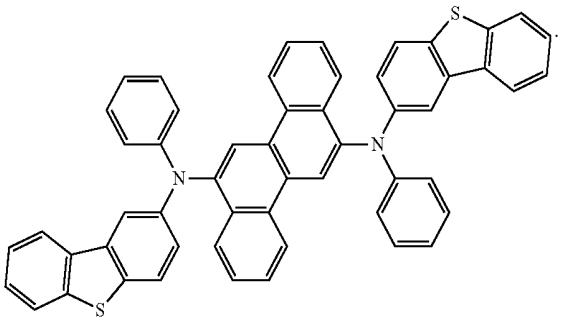
FD8



[0152] The amount of the dopant in the emitting 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.

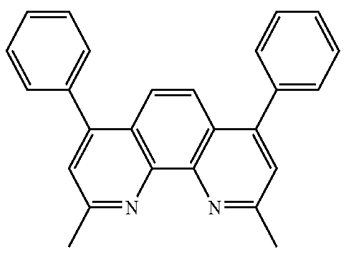
[0153] The thickness of the emitting layer may be about 100 Å to about 1,000 Å, and in some embodiments, about 200 Å to about 600 Å. When the thickness of the emitting layer is within these ranges, excellent light-emission characteristics may be obtained without a substantial increase in driving voltage.

[0154] An electron transport region may be on the emitting layer.

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

[0156] When the electron transport region includes a hole blocking layer, the hole blocking layer may be formed on the emitting layer using one or more suitable methods selected from vacuum deposition, spin coating, casting, a Langmuir-Blodgett (LB) method, ink-jet printing, laser-printing, and laser-induced thermal imaging. When the hole blocking layer is formed by vacuum deposition and/or spin coating, the deposition and coating conditions for the hole blocking layer may be determined by referring to the deposition and coating conditions for the hole injection layer.

[0157] The hole blocking layer may include, for example, at least one selected from BCP and Bphen, but embodiments of the present disclosure are not limited thereto:



BCP

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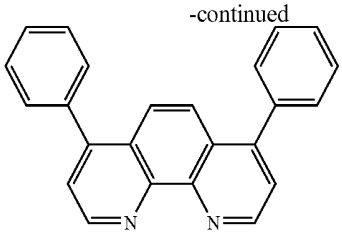


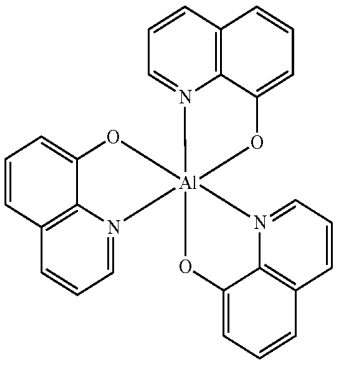
Bphen

[0158] The thickness of the hole blocking layer may be about 20 Å to about 1,000 Å, and in some embodiments, about 30 Å to about 300 Å. When the thickness of the hole blocking layer is within these ranges, the hole blocking layer may have excellent hole blocking characteristics without a substantial increase in driving voltage.

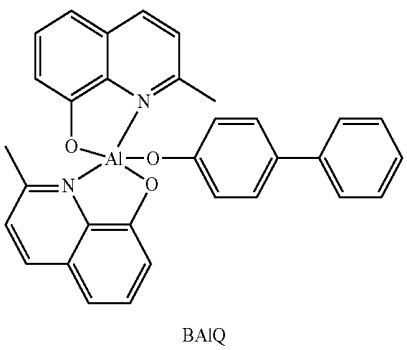
[0159] The electron transport region may have a structure of electron transport layer/electron injection layer and/or a structure of hole blocking layer/electron transport layer/electron injection layer, wherein layers of each structure are sequentially stacked on the emitting layer in each stated order, but embodiments of the present disclosure are not limited thereto.

[0160] In some embodiments, the organic layer **150** of the organic light-emitting device may include an electron transport region between the emitting layer and the second electrode **190**, and the electron transport region may include an electron transport layer. The electron transport layer may include a plurality of layers. For example, the electron transport layer may include a first electron transport layer and a second electron transport layer.

[0161] The electron transport layer may further include at least one selected from BCP, Bphen, Alq_3, Balq, TAZ, and NTAZ:



Alq_3



BAlQ

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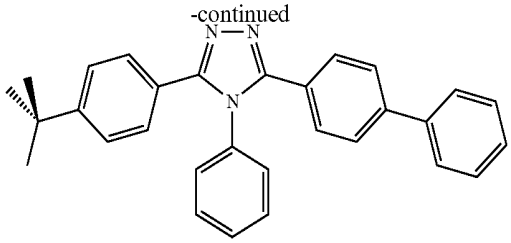
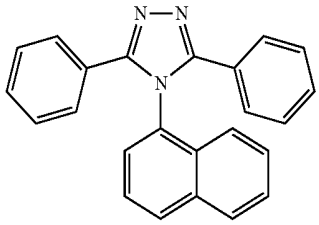


TAZ



NTAZ

[0162] In some embodiments, the electron transport layer may include at least one selected from a compound represented by Formula 601 and a compound represented by Formula 602:

$$Ar_{601}\text{-}[(L_{601})_{xe1}\text{-}E_{601}]_{xe2} \qquad \text{Formula 601}$$

[0163] In Formula 601,

[0164] Ar_{601} may be selected from the group consisting of:

[0165] a naphthalene, a heptalene, a fluorenene, a spiro-fluorene, a benzofluorene, a dibenzofluorene, a phenalene, a phenanthrene, an anthracene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a naphthacene, a picene, a perylene, a pentaphene, and an indenoanthracene;

[0166] a naphthalene, a heptalene, a fluorenene, a spiro-fluorene, a benzofluorene, a dibenzofluorene, a phenalene, a phenanthrene, an anthracene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a naphthacene, a picene, a perylene, a pentaphene, and an indenoanthracene, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a 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_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-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, monovalent non-aromatic condensed heteropolycyclic group, and —$Si(Q_{301})(Q_{302})(Q_{303})$ (wherein Q_{301} to Q_{303} may each independently be selected from hydrogen, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_6-C_{60} aryl group, and a C_1-C_{60} heteroaryl group);

[0167] L_{601} may be selected from the group consisting of: a phenylene group, a naphthylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorene group, a dibenzofluorene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, a chrysenylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a quinolinylene

group, an isoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a carbazolylene group, and a triazinylene group; and

[0168] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorene group, a dibenzofluorene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, a chrysenylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a quinolinylene group, an isoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a carbazolylene group, and a triazinylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a sail thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} akyl group, a C_1-C_{20} akoxy group, a phenyl group a naphlhyl group, a fluoienyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyf group, an isoindolyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

[0169] E_{601} may be selected from the group consisting of:

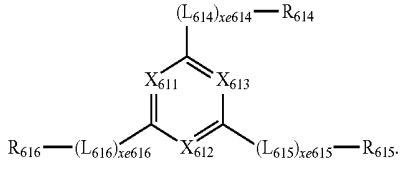
[0170] a pyrrolyl group, a Ihiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyt group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a Ihiadiazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group; and

[0171] a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthytidinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, each substituted with at least one selected from deuterium. —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{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 pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzoftuorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group;

[0172] xe1 may be selected from 0, 1, 2, and 3; and

[0173] xe2 may be selected from 1, 2, 3, and 4.

Formula 602



[0174] In Formula 602,

[0175] X_{611} may be selected from N and C-$(L_{611})_{xe611}$-R_{611}, X_{612} may be selected from N and C-$(L_{612})_{xe612}$-R_{612}, X_{613} may be selected from N and C-$(L_{613})_{xe613}$-R_{613}, and at least one selected from X_{611} to X_{613} may be N;

[0176] L_{611} to L_{616} may each independently be selected from the same groups described herein in connection with L_{601};

[0177] R_{611} to R_{616} may each independently be selected from the group consisting of:

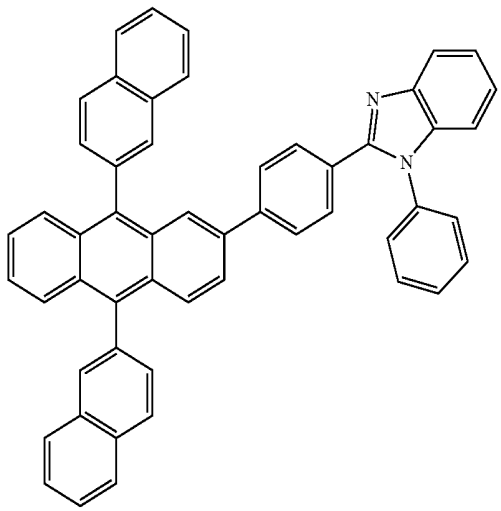
[0178] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

[0179] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

[0180] xe611 to xe616 may each independently be selected from 0, 1, 2, and 3.

[0181] The compound represented by Formula 601 and the compound represented by Formula 602 may each independently be selected from Compounds ET1 to ET15:

ET1



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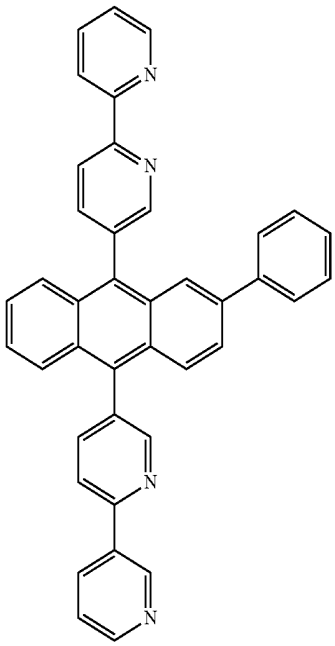
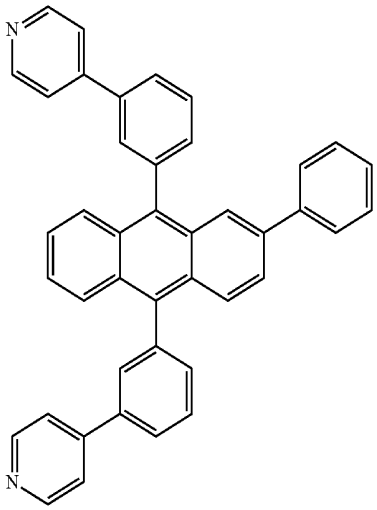
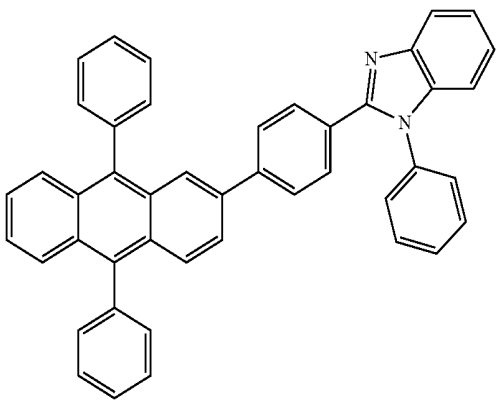
ET2



ET3



ET4



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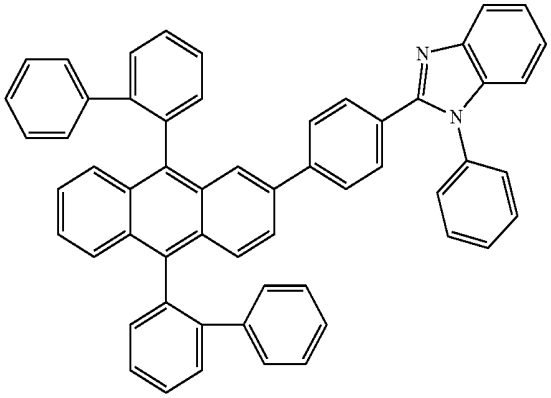
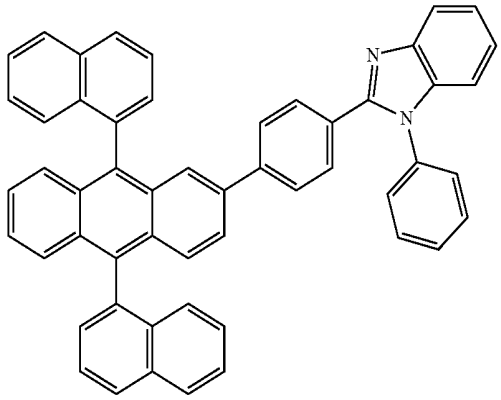
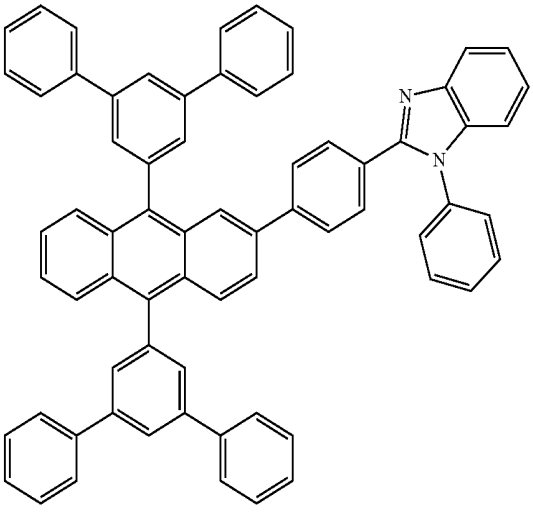
ET5



ET6



ET7



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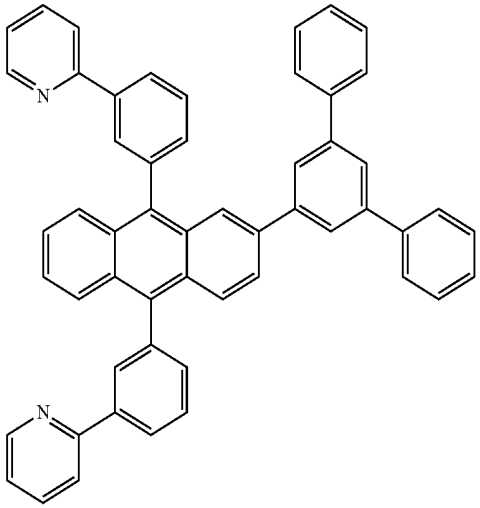
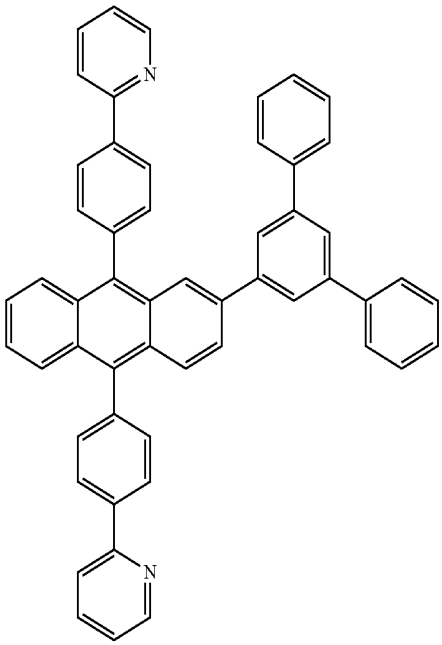
ET8



ET9



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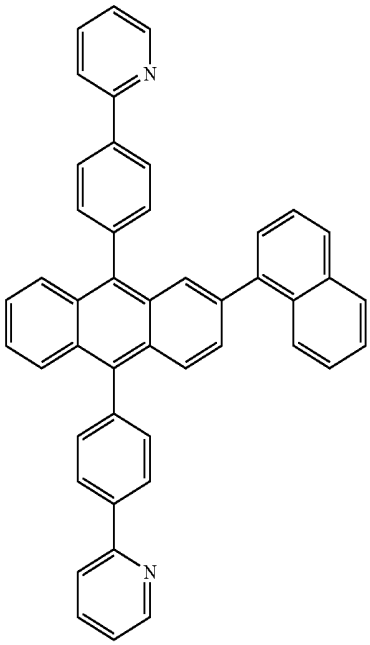
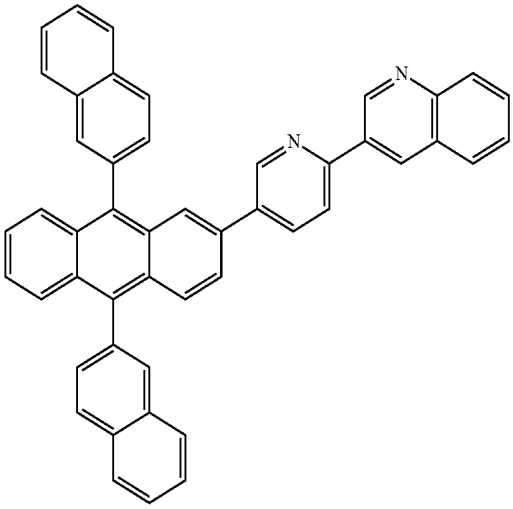
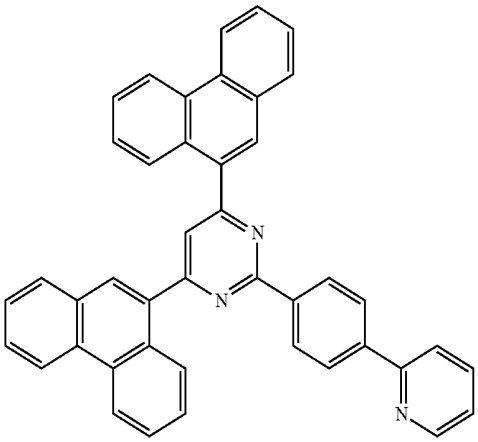
ET10



ET11



ET12



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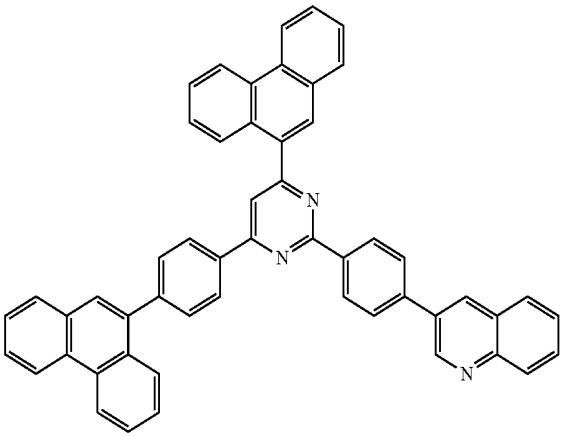
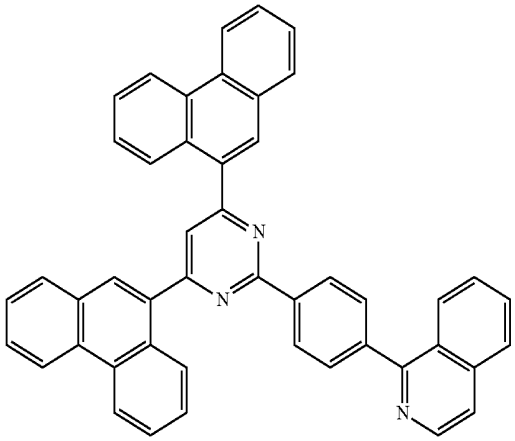
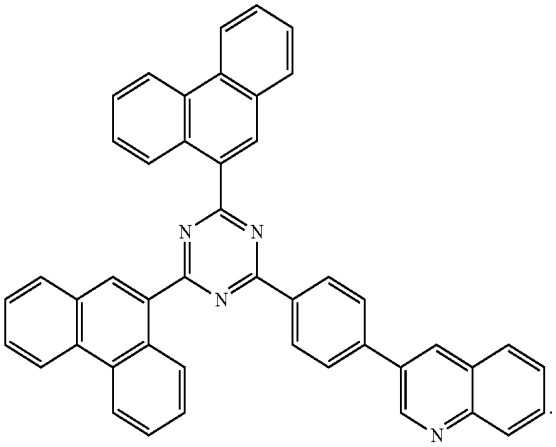
ET13



ET14



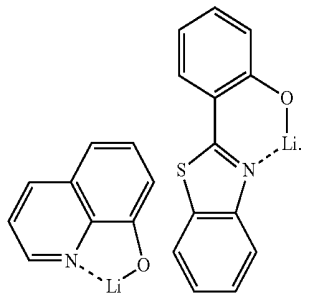
ET15



[0182] 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.

[0183] The electron transport layer may further include, in addition to the materials described above, a metal-containing material.

[0184] The metal-containing material may include a Li complex. The Li complex may be selected from, for example, Compound ET-D1 (lithium quinolate, LiQ) and ET-D2.



ET-D1 ET-D2

[0185] The electron transport region may include an electron injection layer that facilitates the injection of electrons from the second electrode **190**.

[0186] The electron injection layer may be formed on the electron transport layer using one or more suitable methods selected from vacuum deposition, spin coating, casting, a LB method, ink-jet printing, laser-printing, and laser-induced thermal imaging. When an electron injection layer is formed by vacuum deposition and/or spin coating, the deposition and coating conditions for the electron injection layer may be the same as those used for the hole injection layer.

[0187] The electron injection layer may include at least one selected from LiF, NaCl, CsF, Li_2O, BaO, and LiQ.

[0188] 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.

[0189] 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. The material for the second electrode **190** may have a relatively low work function, and may be selected from metal, an alloy, an electrically conductive compound, and mixtures thereof. Non-limiting examples of the material for the second electrode **190** may include lithium (Li), magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), and magnesium-silver (Mg—Ag). In some embodiments, the material for forming the second electrode **190** may be ITO and/or IZO. The second electrode **190** may be a reflective electrode, a semi-transmissive electrode, or a transmissive electrode.

[0190] An organic layer may be formed by depositing the compound according to an embodiment of the present disclosure, or may be formed using a wet method in which the compound according to an embodiment of the present disclosure is prepared in the form of solution and then used for coating.

[0191] An organic light-emitting device according to an embodiment of the present disclosure may be used in various flat panel display apparatuses, such as a passive matrix organic light-emitting display apparatus and/or 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 act as a pixel and may be electrically connected to a source electrode or a drain electrode of a thin film transistor. In some embodiments, the organic light-emitting device may be included in a flat panel display apparatus that emits light in opposite directions.

[0192] Hereinbefore, the organic light-emitting device has been described with reference to the drawing, but embodiments of the present disclosure are not limited thereto.

[0193] Hereinafter, definitions of 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, and unless defined otherwise, the definition of the substituent is consistent with a general definition thereof.

[0194] 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 ted-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.

[0195] 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 isopropyloxy group.

[0196] 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.

[0197] 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.

[0198] 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.

[0199] The term "C_1-C_{10} heterocycloalkyl group" as used herein refers to a monovalent monocyclic group having at least one hetero atom selected from N, O, P, and S as a ring-forming atom and 1 to 10 carbon atoms. Non-limiting examples thereof may include a tetrahydrofuranyl group and a tetrahydrothiophenyl group. The term "C_1-C_{10} heterocycloalkylene group" as used herein refers to a divalent group having substantially the same structure as the C_1-C_{10} heterocycloalkyl group.

[0200] The term "C_3-C_{10} cycloalkenyl group" as used herein refers to a monovalent monocyclic group that has 3 to 10 carbon atoms and at least one double bond in its ring, and is not aromatic. Non-limiting examples thereof may include a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. The term "C_3-C_{10} cycloalkenylene group" as used herein refers to a divalent group having substantially the same structure as the C_3-C_{10} cycloalkenyl group.

[0201] The term "C_2-C_{10} heterocycloalkenyl group" as used herein refers to a monovalent monocyclic group that has at least one hetero atom selected from N, O, P, and S as a ring-forming atom, 2 to 10 carbon atoms, and at least one double bond in its ring. Non-limiting examples of the C_2-C_{10} heterocycloalkenyl group may include a 2,3-hydrofuranyl group and a 2,3-hydrothiophenyl group. The term "C_2-C_{10} heterocycloalkenylene group" as used herein refers to a divalent group having substantially the same structure as the C_2-C_{10} heterocycloalkenyl group.

[0202] The term "C_{60}-C_{60} aryl group" as used herein refers to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms. The term "C_{60}-C_{60} arylene group" as used herein refers to a divalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms. Non-limiting examples of the C_6-C_{60} aryl group may include a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, an anthracenyl group, a phenanthrenyl group, a pyrenyl group, and a chrysenyl group. When the C_6-C_{60} aryl group and the C_6-C_{60} arylene group each include two or more rings, the rings may be fused to each other.

[0203] The term "C_1-C_{60} heteroaryl group" as used herein refers to a monovalent group having a carbocyclic aromatic system that has at least one hetero atom selected from N, O, P, and S as a ring-forming atom, and 1 to 60 carbon atoms. The term "C_1-C_{60} heteroarylene group" as used herein refers to a divalent group having a carbocyclic aromatic system that has at least one hetero atom selected from N, O, P, and S as a ring-forming atom, and 1 to 60 carbon atoms. Non-limiting examples of the C_1-C_{60} heteroaryl group may include a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, and an isoquinolinyl group. When the C_1-C_{60} heteroaryl group and the C_1-C_{60} heteroarylene group each include two or more rings, the rings may be fused to each other.

[0204] The term "C_6-C_{60} aryloxy group" as used herein indicates —O-A_{102} (wherein A_{102} is a C_6-C_{60} aryl group). The term "C_6-C_{60} arylthio group" as used herein indicates —S-A_{103} (wherein A_{103} is a C_6-C_{60} aryl group).

[0205] The term "monovalent non-aromatic condensed polycyclic group" as used herein refers to a monovalent group that has two or more rings condensed to each other, only carbon atoms as a ring forming atom (for example, 8 to 60 carbon atoms), and non-aromaticity in the entire molecular structure (e.g., 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.

[0206] The term "monovalent non-aromatic condensed heteropolycyclic group" as used herein refers to a monovalent group that has two or more rings condensed to each other, has a heteroatom selected from N, O P, and S, as a ring forming atom, has, for example, 2 to 60 carbon atoms, and has non-aromaticity in the entire molecular structure (e.g., is non-aromatic). The term "divalent non-aromatic condensed hetero-polycyclic group" as used herein refers to a divalent group having substantially the same structure as the monovalent non-aromatic condensed heteropolycyclic group.

[0207] In the present specification, at least one substituent of the substituted C_3-C_{10} cycloalkylene group, the substituted C_2-C_{10} heterocycloalkylene group, the substituted C_3-C_{10} cycloalkenylene group, the substituted C_2-C_{10} heterocycloalkenylene 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, the substituted divalent non-aromatic condensed heteropolycyclic group, the substituted C_1-C_{60} alkyl group, the substituted C_2-C_{60} alkenyl group, the substituted C_2-C_{60} alkynyl group, the substituted C_1-C_{60} alkoxy group, the substituted C_3-C_{10} cycloalkyl group, the substituted C_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, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from the group consisting of:

[0208] 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;

[0209] a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_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_2-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 —$B(Q_{16})(Q_{17})$,

[0210] 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;

[0211] 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_2-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_1-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 —$B(Q_{26})(Q_{27})$, and

[0212] —$N(Q_{31})(Q_{32})$, —$Si(Q_{33})(Q_{34})(Q_{35})$, and —$B(Q_{36})(Q_{37})$,

[0213] Q_{11} to Q_{17}, Q_{21} to Q_{27}, and Q_{31} to Q_{37} may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a 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.

[0214] For example, at least one substituent of the substituted C_3-C_{10} cycloalkylene group, the substituted C_2-C_{10} heterocycloalkylene group, the substituted C_3-C_{10} cycloalkenylene group, the substituted C_2-C_{10} heterocycloalkenylene 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, the substituted divalent non-aromatic condensed heteropolycyclic group, the substituted C_1-C_{60} alkyl group, the substituted C_2-C_{60} alkenyl group, the substituted C_2-C_{60} alkynyl group, the substituted C_1-C_{60} alkoxy group, the substituted C_3-C_{10} cycloalkyl group, the substituted C_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, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from the group consisting of:

[0215] 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;

[0216] 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 sail thereof, a sulfonic acid group or a sail thereof, a phosphoric acid group or a salt thereof, a cyclopenlyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, —$N(Q_{11})(Q_{12})$, —$Si(Q_{13})(Q_{14})(Q_{15})$, and —$B(Q_{16})(Q_{17})$;

[0217] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group; and

[0218] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an

indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group, 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 sail thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, —$N(Q_{21},)(Q_{22})$, —$Si(Q_{23})(Q_{24})(Q_{25})$, and —$B(Q_{26})(Q_{27})$; and

[0219] —$N(Q_{31})(Q_{32})$, —$Si(Q_{33})(Q_{34})(Q_{35})$, and —$B(Q_{36})(Q_{37})$;

[0220] wherein Q_{11} to Q_{17}, Q_{21} to Q_{27}, and Q_{31} to Q_{37} may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group.

[0221] 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, and the term "ter-Bu" and/or Bu^t as used herein refers to a tert-butyl group.

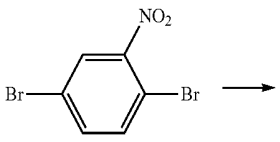
[0222] Hereinafter, an organic light-emitting device according to an embodiment of the present disclosure will be described in more detail with reference to Synthesis Examples and Examples.

Synthesis Example

Synthesis Example 1

Synthesis of Compound 4

[0223]



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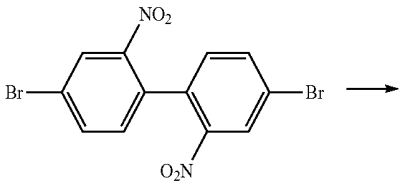

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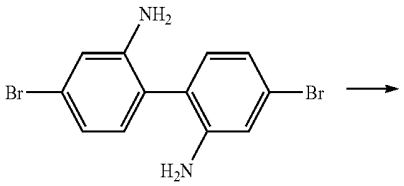

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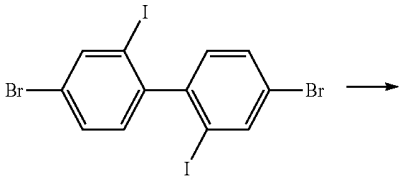

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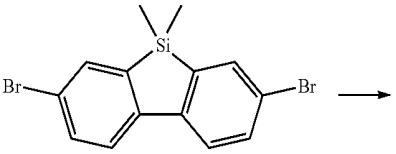

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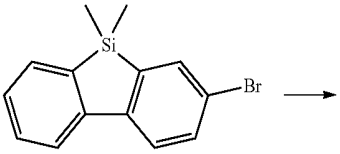

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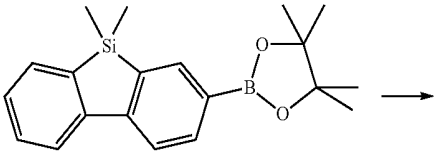

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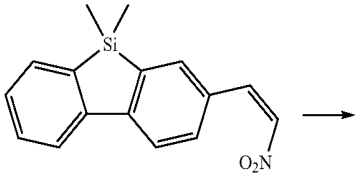

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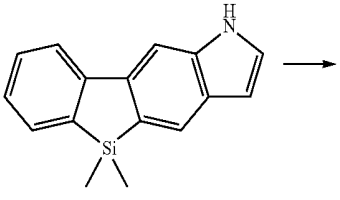

4-8

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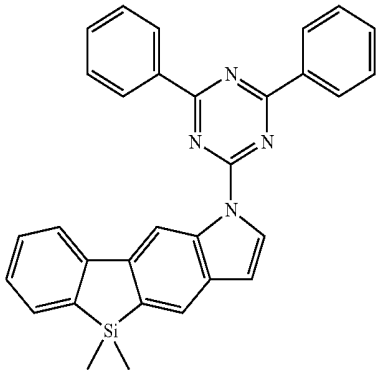


Compound 4

Synthesis of Intermediate 4-1

[0224] 50.0 g (179 mmol) of 1,4-dibromo-2-nitrobenzene was dissolved in 200 mL of dimethylformamide (DMF) and 27.0 g (424 mmol) of copper powder was added thereto. The mixture was stirred at a temperature of about 125° C. for about 3 hours. The reaction mixture was cooled to room temperature, and then subjected to filtration to remove the precipitate therefrom. The resultant solid was dried, then washed with 500 mL of MeOH, thereby producing 27.1 g (yield: 88%) of Intermediate 4-1.

Synthesis of Intermediate 4-2

[0225] 15 g (37.3 mmol) of Intermediate 4-1 was dissolved in 200 mL of ethanol, and 120 mL of a 32% (w/w) HCl aqueous solution was added thereto. At room temperature, 17.6 g (147 mmol) of tin powder was added portionwise thereto and stirred at a temperature of about 100° C. for about 2 hours. The resulting mixture was cooled to room temperature, and then added to ice water. 150 mL of a 20% (w/w) NaOH aqueous solution was added thereto to make the resultant solution to have a basic pH. An extraction process was performed thereon using diethyl ether, and then, the resultant was washed with brine, dried, and then recrystallized using ethanol, thereby producing 9.2 g (yield: 72%) of Intermediate 4-2.

Synthesis of Intermediate 4-3

[0226] At a temperature of about 0° C., 85 mL of a 17% (w/w) HCl aqueous solution and a $NaNO_2$ aqueous solution including 4.3 g (62 mmol) of $NaNO_2$ and 15 mL of water were added to a round-bottom flask containing 8.5 g (25 mmol) of Intermediate 4-2. The resulting mixture was stirred for about 30 minutes, and a KI aqueous solution including 41.5 g (250 mmol) of KI and 15 mL of water was added thereto, followed by stirring for about 1 hour at room temperature and then stirring at a temperature of about 60° C. for about 3 hours. A saturated KOH solvent was used to neutralize the resulting mixture. An organic layer was extracted therefrom using ethyl acetate, washed with saturated Na_2SO_3, and purified through silica gel chromatography, thereby producing 4 g (yield: 29%) of Intermediate 4-3.

Synthesis of Intermediate 4-4

[0227] A round-bottom flask containing 4 g (7.1 mmol) of Intermediate 4-3 was filled with argon gas and 30 mL of

tetrahydrofuran (THF). The resulting mixture was then cooled to a temperature of about −78° C. 6.2 mL (15.6 mmol) of n-BuLi (2.5 molar (M) in hexane) was slowly added thereto, and the resulting solution was stirred for about 1 hour. 2.0 g (15.6 mmol) of dichlorodimethyl silane was added thereto. The resulting solution was stirred for about 12 hours and the temperature was allowed to slowly come to room temperature. An organic layer was extracted using ethyl acetate and washed with water. The obtained organic layer was dried and purified through silica gel chromatography, thereby producing 2 g (yield: 76%) of Intermediate 4-4.

Synthesis of Intermediate 4-5

[0228] A round-bottom flask containing 2 g (5.43 mmol) of Intermediate 4-4 was filled with argon gas and 25 mL of THF. The resulting mixture was cooled to a temperature of about −78° C. 2.2 mL (5.43 mmol) of n-BuLi (2.5 M in hexane) was slowly added thereto, and the resulting solution was stirred for about 1 hour. 20 mL of 1 M HCl was added thereto and stirred for about 2 hours. Once the stirring was complete, an organic layer was extracted using ethyl acetate and washed with water. The obtained organic layer was dried and purified through silica gel chromatography, thereby producing 1.5 g (yield: 96%) of Intermediate 4-5.

Synthesis of Intermediate 4-6

[0229] A round-bottom flask containing 15 g (51.9 mmol) of Intermediate 4-5 was filled with argon gas and 300 mL of THF. The resulting mixture was cooled to a temperature of about −78° C. 20.8 mL (51.9 mmol) of n-BuLi (2.5 M in hexane) was slowly added thereto, and the resulting solution was stirred for about 1 hour. 335 mg (62.3 mmol) of 2-isopropoxy-4,4,5,5-tetramethyl-1,3,2-dioxaborolane was added thereto, the resulting solution was stirred for about 12 hours, and the temperature was allowed to slowly come to room temperature. An organic layer was extracted using ethyl acetate and washed with water. The obtained organic layer was dried and purified through silica gel chromatography, thereby producing 12 g (yield: 69%) of Intermediate 4-6.

Synthesis of Intermediate 4-7

[0230] 6.46 g (42.8 mmol) of 1-bromo-2-nitroethane and 1.24 g (1.07 mmol) of $Pd(PPh_3)_4$ was added to a round-bottom flask containing 12 g (35.7 mmol) of Intermediate 4-6, and the round-bottom flask was filled with argon gas. 120 mL of toluene, 60 mL of ethanol, and 60 mL of 2 M K_2CO_3 were added thereto, and the solution was stirred under reflux for about 4 hours. The resulting solution was cooled to room temperature. An organic layer was extracted therefrom using ethyl acetate and washed with water. The obtained organic layer was dried and purified through silica gel chromatography, thereby producing 7.5 g (yield: 75%) of Intermediate 4-7.

Synthesis of Intermediate 4-8

[0231] A round-bottom flask containing 8.1 g (28.7 mmol) of Intermediate 4-7 was filled with argon gas, 100 mL of triethylphosphite and 500 mL of 1,2-dichlorobenzene were added thereto, and the solution was stirred under reflux for about 12 hours. The resulting solution was cooled to room temperature. An organic layer was extracted therefrom using ethyl acetate and washed with water. The obtained organic layer was dried and purified through silica gel chromatography, thereby producing 5.9 g (yield: 82%) of Intermediate 4-8.

Synthesis of Compound 4

[0232] 2.5 g (10.0 mmol) of Intermediate 4-8 dissolved in 200 mL of DMF was slowly added to a round-bottom flask containing 288 mg (12 mmol) of NaH and 100 mL of DMF. The resulting mixture was stirred for about 1 hour. 2.7 g (10 mmol) of 2-chloro-4,6-diphenyl-1,3,5-triazine was dissolved in 200 mL of DMF and slowly added to the reaction mixture. The resulting solution was stirred at room temperature for about 12 hours. The resulting product was filtered and washed with water and MeOH, thereby producing 2.0 g (yield: 41%) of Compound 4.

[0233] Mass spectrometry (MS): m/z 480.65 [M]+

[0234] ^{1}H NMR ($CDCl_3$) δ 8.36 (4H), 8.02 (1H), 7.87 (1H), 7.84 (1H), 7.65 (1H), 7.60 (1H), 7.50 (6H), 7.47 (1H), 6.52 (1H), 0.66 (6H)

Synthesis Example 2

Synthesis of Compound 7

[0235] Compound 7 (yield: 33%) was obtained in substantially the same manner as in Synthesis Example 1, except that dichlorodiphenyl silane was used instead of dichlorodimethyl silane.

[0236] MS: m/z 604.79 [M]+

[0237] ^{1}H NMR ($CDCl_3$) δ 8.36 (4H), 8.02 (1H), 7.87 (1H), 7.84 (1H), 7.65 (1H), 7.60 (2H), 7.50 (6H), 7.47 (1H), 7.46 (4H), 7.38 (6H), 6.52 (1H)

Synthesis Example 3

Synthesis of Compound 8

[0238] Compound 8 (yield: 43%) was obtained in substantially the same manner as in Synthesis Example 1, except that 2-chloro-4,6-diphenylpyrimidine was used instead of 2-chloro-4,6-diphenyl-1,3,5-triazine.

[0239] MS: m/z 479.66 [M]+

[0240] ^{1}H NMR ($CDCl_3$) δ 8.59 (1H), 8.02 (1H), 7.94 (4H), 7.87 (1H), 7.84 (1H), 7.65 (1H), 7.60 (2H), 7.55 (4H), 7.49 (2H), 7.47 (1H), 6.52 (1H), 0.66 (6H)

Synthesis Example 4

Synthesis of Compound 9

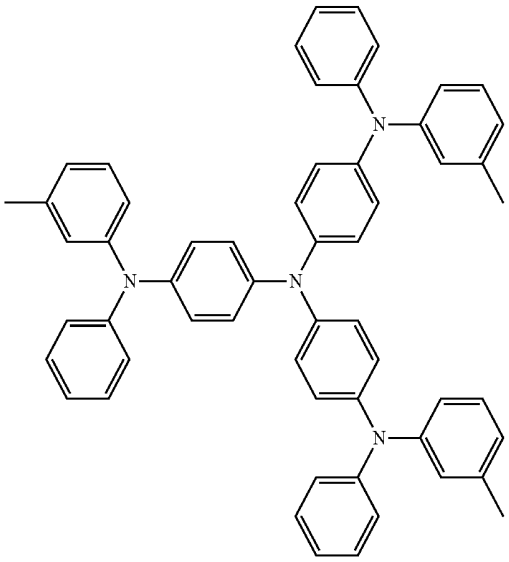
[0241] Compound 9 (yield: 34%) was obtained in substantially the same manner as in Synthesis Example 3, except that dichlorodiphenyl silane was used instead of dichlorodimethyl silane.

[0242] MS: m/z 603.80 [M]+

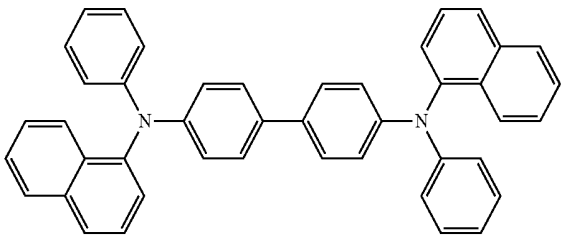
[0243] ^{1}H NMR ($CDCl_3$) δ 8.59 (1H), 8.02 (1H), 7.94 (4H), 7.87 (1H), 7.84 (1H), 7.65 (1H), 7.60 (2H), 7.55 (4H), 7.49 (2H), 7.47 (1H), 7.46 (4H), 7.38 (6H), 6.52 (1H)

Example 1

[0244] An ITO glass substrate (50 millimeters (mm)×50 mm and 15 Ohms per square centimeter (Ω/cm^2)) as an OLED glass (available from Samsung-Corning) substrate was sequentially sonicated using distilled water and isopropyl alcohol, and cleaned by exposure to ultraviolet rays with ozone for about 30 minutes. Once the sonication was complete, the glass substrate with a transparent electrode line attached thereto was mounted on a vacuum deposition device. 4,4',4"-Tris(N-(2-naphthyl)-N-phenyl-amino)-triphenylamine (2T-NATA) was deposited (via resistance heating deposition) on the ITO electrode (anode) to form a hole injection layer having a thickness of about 60 nm. N,N'-bis(naphthalen-1-yl)-N,N'-bis(phenyl)benzidine (NPB) was deposited on the hole injection layer to form a hole transport layer having a thickness of about 20 nm. Compound 4 and $Ir(ppy)_3$ (Tris(2-phenyl pyridine)iridium(III)) (as a dopant, 8 wt. %) were then co-deposited on the hole transport layer to form an emitting layer having a thickness of about 30 nm. Compound 201 was next deposited on the emitting layer to form an electron transport layer having a thickness of about 20 nm. LiQ (8-Hydroxyquinolinolato-lithium) was deposited on the electron transport layer to form an electron injection layer having a thickness of about 1 nm, and aluminum (Al) was then deposited on the electron injection layer to form a cathode having a thickness of about 100 nm, thereby completing the manufacture of an organic light-emitting device. Deposition equipment (Sunicel plus 200) manufactured by Sunic System Ltd. was used in the deposition.



2T-NATA



NPB

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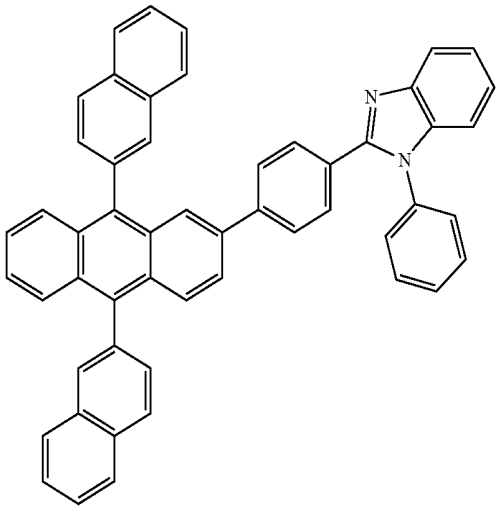
Compound 201



Example 2

[0245] An organic light-emitting device was manufactured in substantially the same manner as in Example 1, except that Compound 7 was used instead of Compound 4 in the formation of the emitting layer.

Example 3

[0246] An organic light-emitting device was manufactured in substantially the same manner as in Example 1, except that Compound 8 was used instead of Compound 4 in the formation of the emitting layer.

Example 4

[0247] An organic light-emitting device was manufactured in substantially the same manner as in Example 1, except that Compound 9 was used instead of Compound 4 in the formation of the emitting layer.

Comparative Example 1

[0248] An organic light-emitting device was manufactured in substantially the same manner as in Example 1, except that CBP was used instead of Compound 4 in the formation of the emitting layer.

[0249] The result of measurement of the driving voltages, current efficiencies (cd/A), color-coordinates, and lifespan (T95) of the organic light-emitting devices manufactured in Examples 1 to 4 and Comparative Example 1 are shown in Table 1:

TABLE 1

	Emitting layer	Driving voltages	Efficiency	Color-coordinate		T95 lifespan
	Host	[V]	[cd/A]	CIEx	CIEy	[hr]
Example 1	Compound 4	4.2	29.5	0.312	0.603	220
Example 2	Compound 7	4.2	27.2	0.309	0.602	280
Example 3	Compound 8	4.2	26.9	0.312	0.602	200

TABLE 1-continued

	Emitting layer	Driving voltages	Efficiency	Color-coordinate		T95 lifespan
	Host	[V]	[cd/A]	CIEx	CIEy	[hr]
Example 4	Compound 9	4.1	26.4	0.310	0.604	230
Comparative Example 1	CBP	5.5	25.2	0.312	0.605	80

[0250] The color-coordinate was measured using a luminance meter PR650 powered by a current voltmeter (Keithley SMU 236).

[0251] The luminance was measured using a luminance meter PR650 powered by a current voltmeter (Keithley SMU 236).

[0252] The efficiency was measured using a luminance meter PR650 powered by a current voltmeter (Keithley SMU 236).

[0253] The T95 lifespan indicates a time (hour) for the luminance of the organic light-emitting device to decline to 95% of its initial luminance (at 10 mA/cm^2).

[0254] When the compound represented by Formula 1 according to an example embodiment is used as a material for an emitting layer, an organic light emitting device including the compound may have decreased driving voltage and improved efficiency, as compared to compounds that are known in the related art. For example, the half lifespan of the device may increase.

[0255] An organic light-emitting device according to an embodiment of the present disclosure may have high efficiency, a low voltage, high luminance, and/or a long lifespan.

[0256] It should be understood that example embodiments described herein should be considered in a descriptive sense only and not for purposes of limitation.

[0257] Descriptions of features or aspects within each example embodiment should typically be considered as available for other similar features or aspects in other example embodiments.

[0258] As used herein, the terms "use", "using", and "used" may be considered synonymous with the terms "utilize", "utilizing", and "utilized", respectively. Further, the use of "may" when describing embodiments of the present disclosure refers to "one or more embodiments of the present disclosure".

[0259] 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.

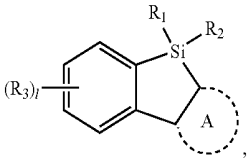
[0260] Also, any numerical range recited herein is intended to include all subranges of the same numerical precision subsumed within the recited range. For example, a range of "1.0 to 10.0" is intended to include all subranges between (and including) the recited minimum value of 1.0 and the recited maximum value of 10.0, that is, having a minimum value equal to or greater than 1.0 and a maximum value equal to or less than 10.0, such as, for example, 2.4 to 7.6. Any maximum numerical limitation recited herein is intended to include all lower numerical limitations subsumed therein and any minimum numerical limitation recited in this specification is intended to include all higher numerical limitations subsumed therein. Accordingly, Applicant reserves the right to amend this specification, including the claims, to expressly recite any sub-range subsumed within the ranges expressly recited herein.

[0261] While one or more example embodiments have been described with reference to the drawing, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope as defined by the following claims, and equivalents thereof.

What is claimed is:

1. A compound represented by Formula 1:

Formula 1



wherein, in Formula 1,

R_1 to R_3 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 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;

A indicates a moiety formed by fusing a substituted or unsubstituted indole group;

I is an integer selected from 0 to 4; and

at least one substituent of the substituted C_1-C_{60} alkyl group, substituted C_2-C_{60} alkenyl group, substituted C_2-C_{60} alkynyl group, substituted C_1-C_{60} alkoxy group, substituted C_3-C_{10} cycloalkyl group, substituted C_2-C_{10} heterocycloalkyl group, substituted C_3-C_{10} cycloalkenyl group, substituted C_2-C_{10} heterocycloalkenyl group, substituted C_6-C_{60} aryl group, substituted C_6-C_{60} aryloxy group, substituted C_6-C_{60} arylthio group, substituted C_2-C_{60} heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent 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 car-

boxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group;

a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_3-C_{10} cycloalkyl group, a C_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_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —$N(Q_{11})(Q_{12})$, —$Si(Q_{13})(Q_{14})(Q_{15})$, and —$B(Q_{16})(Q_{17})$,

a C_3-C_{10} cycloalkyl group, a C_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_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group; and

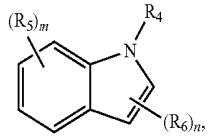
a C_3-C_{10} cycloalkyl group, a C_2-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_2-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, 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_2-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 —$B(Q_{26})(Q_{27})$;

wherein Q_{11} to Q_{17} and Q_{21} to Q_{27} are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_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.

2. The compound of claim **1**, wherein a plurality of adjacent R_3(s) are connected to each other to form a ring.

3. The compound of claim **1**, wherein A indicates a moiety formed by fusing Formula 1-1:

Formula 1-1



wherein, in Formula 1-1, R_5 to R_6 are the same as described in R_1 to R_3;

m is an integer selected from 0 to 4; and

n is an integer selected from 0 to 2.

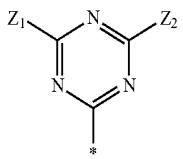
4. The compound of claim **3**, wherein A indicates a moiety formed by fusing a phenyl moiety in Formula 1-1; and m is an integer selected from 0 to 2.

5. The compound of claim **1**, wherein R_1 and R_2 are each independently selected from a phenyl group, a biphenyl group, a terphenyl group, and a methyl group.

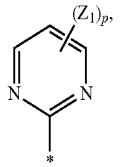
6. The compound of claim **3**, wherein R_3 and R_6 are each independently selected from hydrogen and deuterium.

7. The compound of claim **3**, wherein R_4 is one selected from the following formulae:

2a



2b



wherein Z_1 and Z_2 are each independently selected from hydrogen, deuterium, a halogen group, a cyano group, a nitro group, a hydroxyl group, a carboxy group, a substituted or unsubstituted C1 to C20 alkyl group, a substituted or unsubstituted C6 to C20 aryl group, a substituted or unsubstituted C1 to C20 heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group;

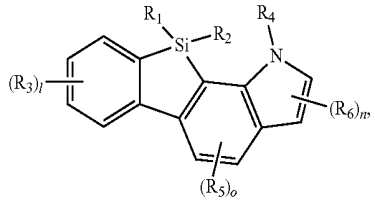
p is an integer selected from 1 to 3;

* indicates a binding site; and

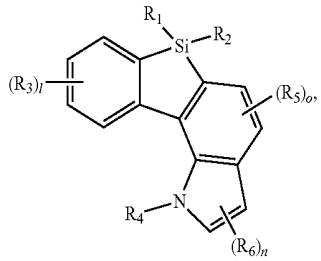
when p is two or more, each Z_1 group is identical to or different from each other.

8. The compound of claim **3**, wherein Formula 1 is represented by one selected from Formulae 2 to 7:

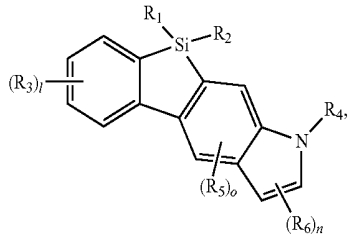
Formula 2



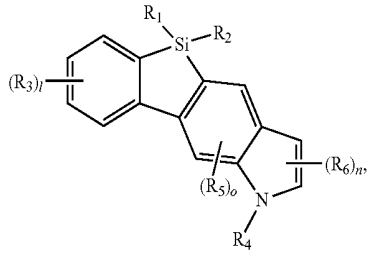
Formula 3



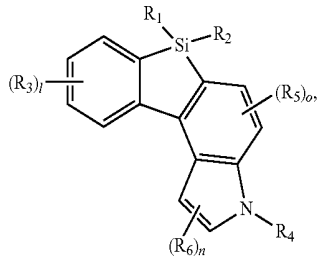
Formula 4



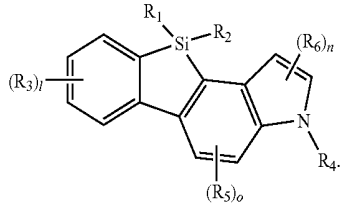
Formula 5



Formula 6



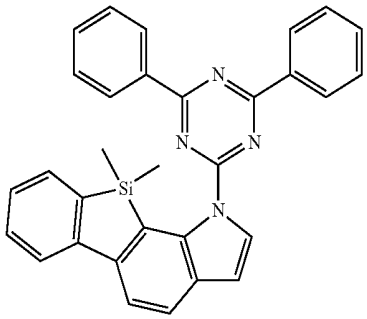
Formula 7



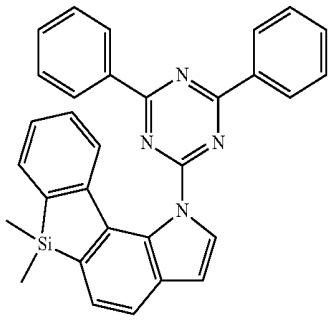
wherein o is an integer selected from 0 to 2.

9. The compound of claim **1**, wherein the compound represented by Formula 1 is selected from the following compounds:

1



2



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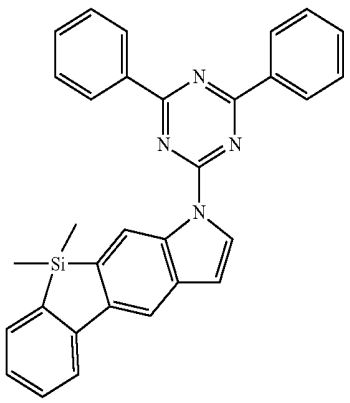

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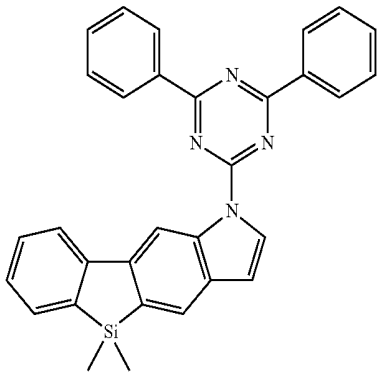

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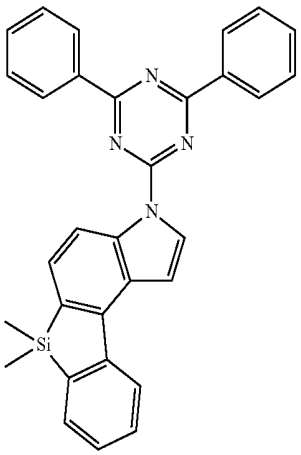

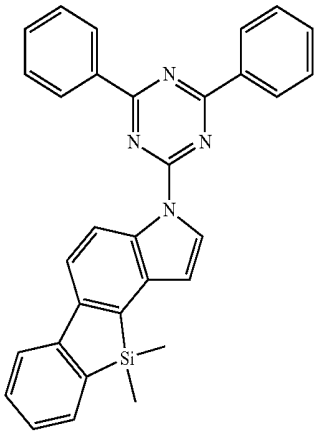

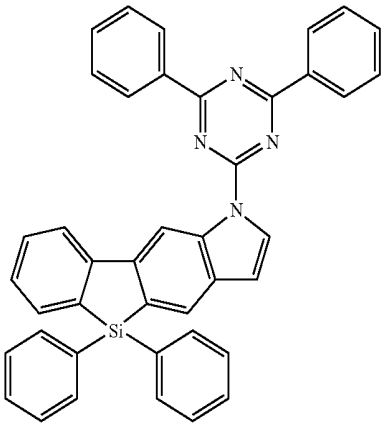

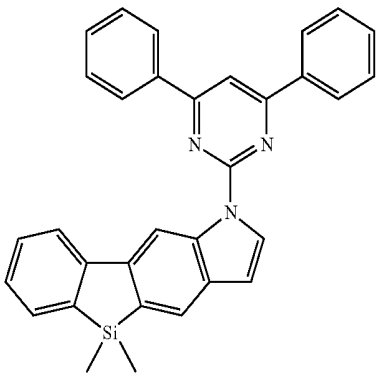

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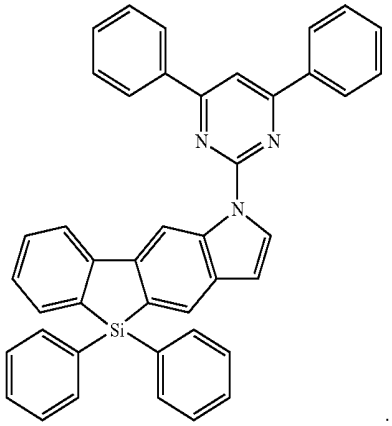


10. An organic light-emitting device comprising:

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 emitting layer,

wherein the organic layer comprises the compound of claim **1**.

11. The organic light-emitting device of claim **10**, wherein the emitting layer comprises the compound.

12. The organic light-emitting device of claim **10**, 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 emitting layer, the hole transport region comprising at least one selected from a hole injection layer, a hole transport layer, and an electron blocking layer, and

ii) an electron transport region between the emitting layer and the second electrode, the electron transport region comprising at least one selected from a hole blocking layer, an electron transport layer, and an electron injection layer.

13. The organic light-emitting device of claim **12**, wherein the electron transport region comprises at least one compound selected from a compound represented by Formula 601 and a compound represented by Formula 602:

$$Ar_{601}\text{-}[(L_{601})_{xe1}\text{-}E_{601}]_{xe2}, \qquad \text{Formula 601}$$

wherein, in Formula 601,

Ar_{601} is selected from the group consisting of:

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

a naphthalene, a heptalene, a fluorene, a spiro-fluorene, a benzofluorene, a dibenzofluorene, a phenalene, a phenanthrene, an anthracene, a fluoranthene, a triphenylene, a pyrene, a chrysene, naphthacene, a picene, a perylene, a pentaphene, and an indenoanthracene, each substituted with at least one selected from deuterium,

—F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-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_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group and —$Si(Q_{301})(Q_{302})(Q_{303})$ (wherein Q_{301} to Q_{303} are each independently selected from hydrogen, C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_6-C_{60} aryl group, and a C_2-C_{60} heteroaryl group;

L_{601} is selected from the group consisting of: a phenylene group, a naphthylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorene group, a dibenzofluorene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, a chrysenylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a quinolinylene group, an isoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a carbazolylene group, and a triazinylene group; and

a phenylene group, a naphthylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, a chrysenylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a quinolinylene group, an isoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a carbazolylene group and a triazinylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyi group, a pyridazinyl group, an isoindolyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group and a triazinyl group;

E_{601} is selected from the group consisting of:

a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyi group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group; and

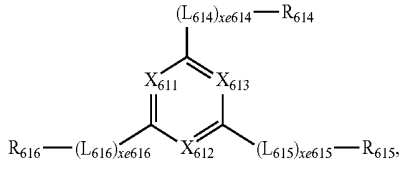
a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a sail thereof, a phosphoric acid group or a salt thereof, 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 pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an

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

xe1 is selected from 0, 1, 2, and 3;

xe2 is selected from 1, 2, 3, and 4;

Formula 602



wherein, in Formula 602,

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

L_{611} to L_{616} are each the same as described in connection with L_{601};

R_{611} to R_{616} are each independently selected from the group consisting of:

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

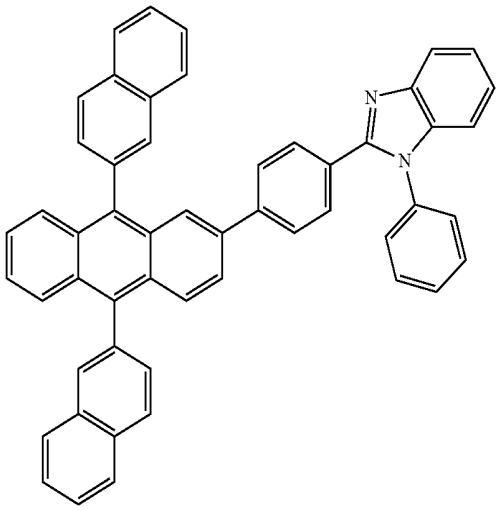
a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl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

xe611 to xe616 are each independently selected from 0, 1, 2, and 3.

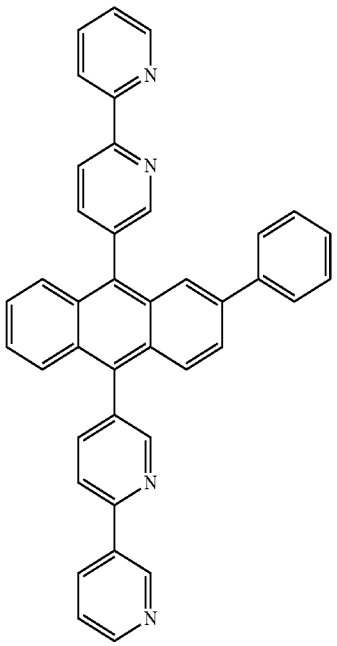
14. The organic light-emitting device of claim **13**, wherein the electron transport layer of the electron transport region comprises the at least one selected from a compound represented by Formula 601 and a compound represented by Formula 602.

15. The organic light-emitting device of claim **13**, wherein the compound represented by Formula 601 and the compound represented by Formula 602 are each independently selected from Compounds ET1 to ET15:

ET1



ET2



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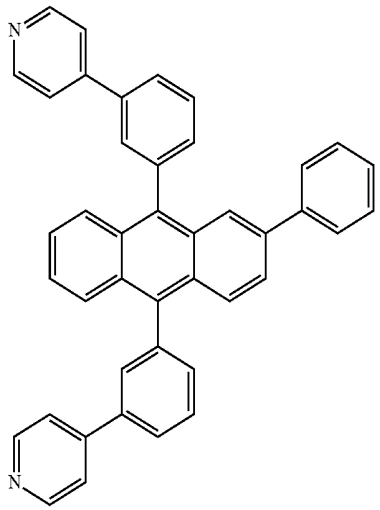
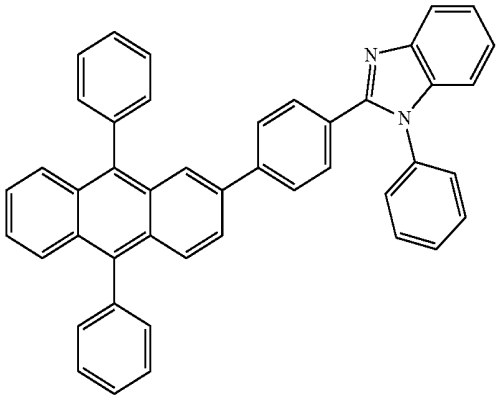
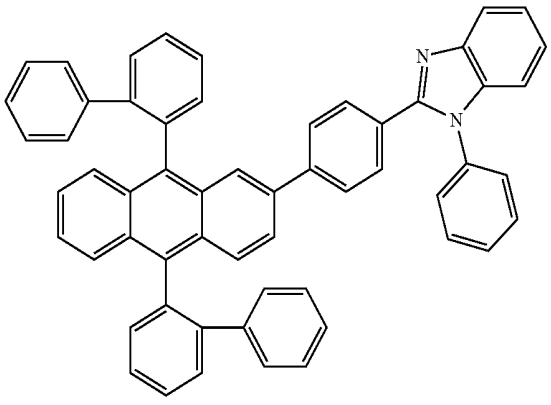
ET3



ET4



ET5



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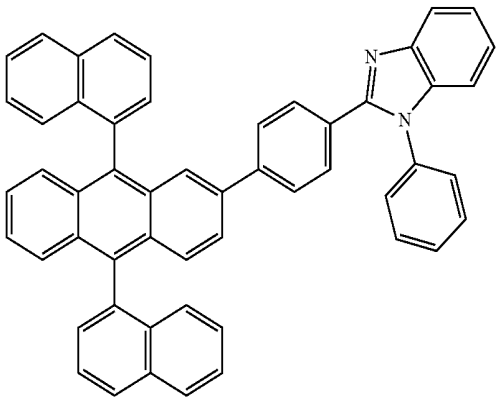
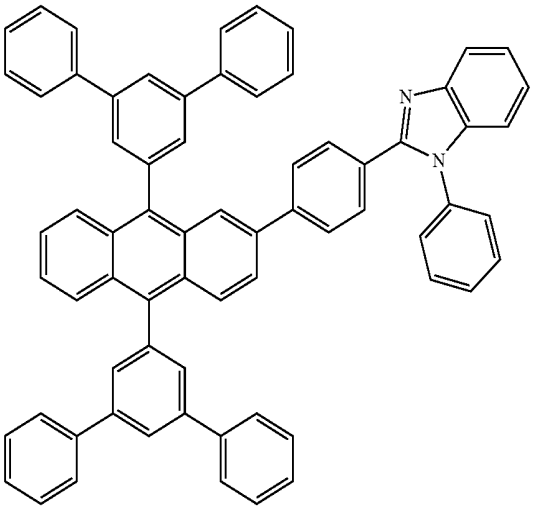
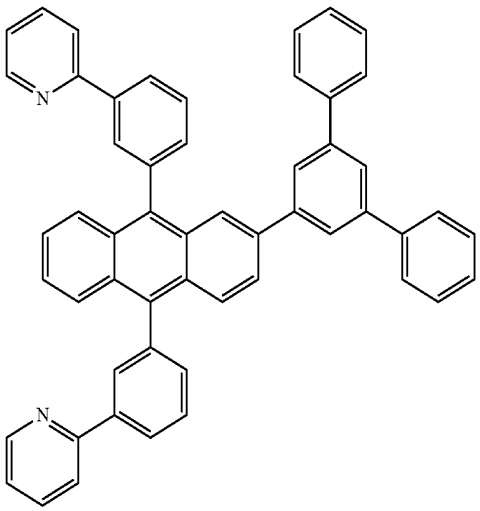
ET6



ET7



ET8



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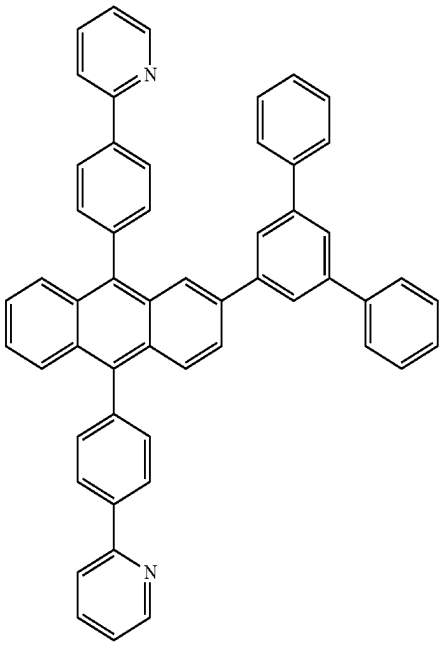
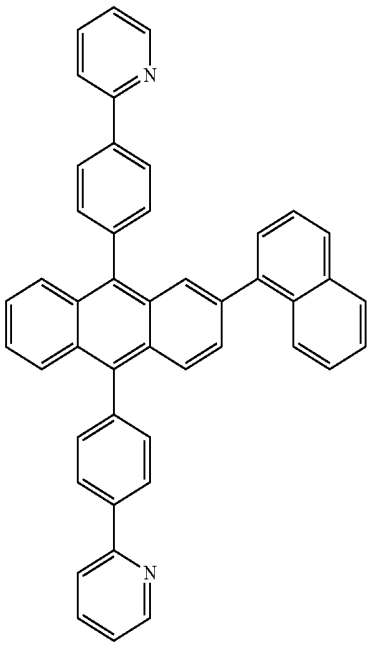
ET9



ET10



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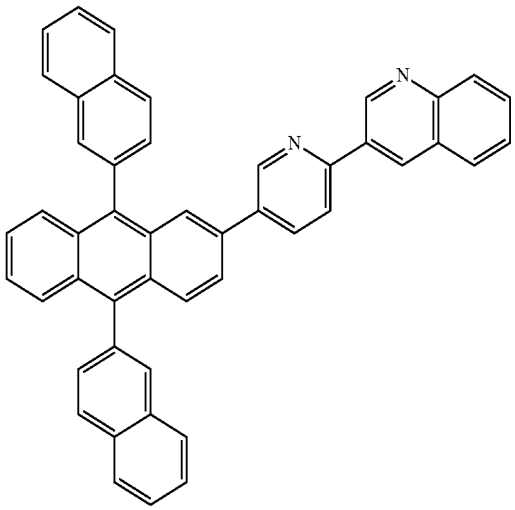
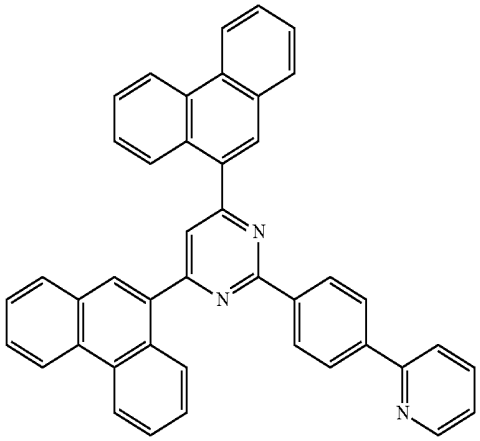
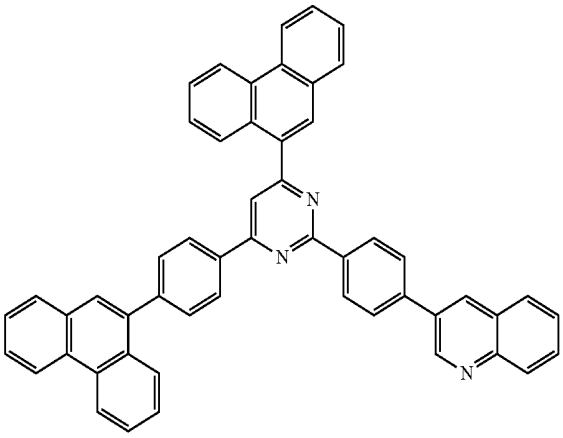
ET11



ET12



ET13



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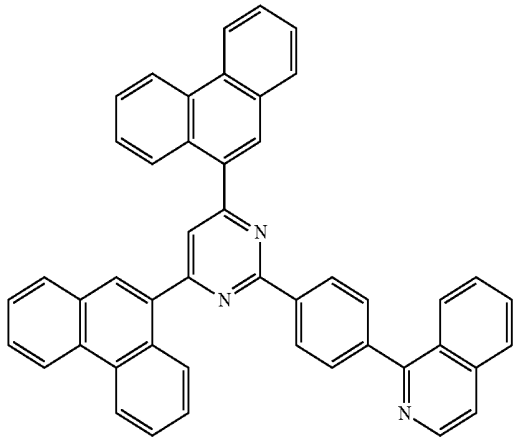
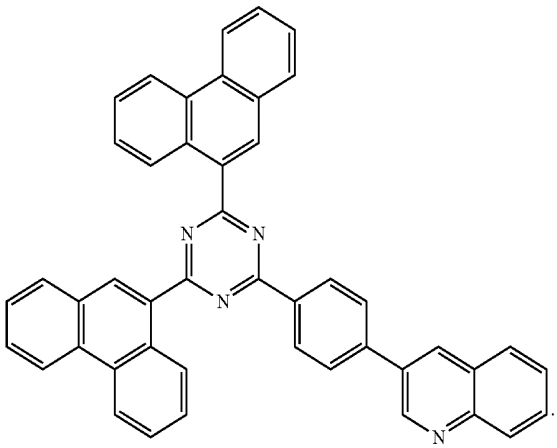
ET14



ET15

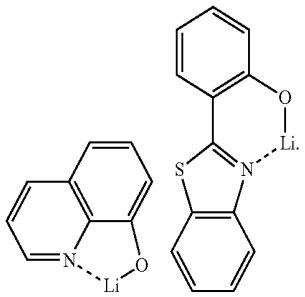


16. The organic light-emitting device of claim **12**, wherein the hole transport region comprises a charge-generating material.

17. The organic light-emitting device of claim **16**, wherein the charge-generating material is a p-dopant.

18. The organic light-emitting device of claim **12**, wherein the electron transport region comprises a metal complex.

19. The organic light-emitting device of claim **12**, wherein the electron transport region comprises one selected from ET-D1 and ET-D2:



ET-D1

ET-D2

20. A display apparatus comprising the organic light-emitting device of claim **10**, 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)	包括其的化合物和有机发光装置		
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[标]申请(专利权)人(译)	三星显示有限公司		
申请(专利权)人(译)	三星DISPLAY CO.，LTD.		
当前申请(专利权)人(译)	三星DISPLAY CO.，LTD.		
[标]发明人	KIM SE HUN CHO HWAN HEE HWANG JIN SOO		
发明人	KIM, SE-HUN CHO, HWAN-HEE HWANG, JIN-SOO		
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摘要(译)

一种具有高玻璃化转变温度，高电稳定性和/或高发光效率的化合物，以及包括含有该化合物的发光层的有机发光装置，其由式1表示： 在式1中，A可以是通过熔合取代或未取代的吲哚基团形成的部分，如式1-1所示： 当由式1表示的化合物用作发光层的材料时，与包含相关领域中可获得的化合物的OLED相比，包含该化合物的有机发光装置可显示出降低的驱动电压和改进的效率和寿命。