ORGANIC LIGHT-EMITTING DEVICE

An organic light-emitting device comprises: a first electrode; a second electrode; and an organic layer between the first electrode and the second electrode, the organic layer comprising an emission layer and a hole transport region, wherein the hole transport region is between the first electrode and the emission layer, and the hole transport region comprises a first compound represented by Formula 1 and a second compound represented by Formula 2:

**Formula 1**

![Formula 1 diagram]

**Formula 2**

![Formula 2 diagram]
FIG. 1
FIELD OF THE INVENTION

[0001] The present invention relates to an organic light-emitting device.

BACKGROUND OF THE INVENTION

[0002] Organic light emitting devices are self-emission devices that have wide viewing angles, high contrast ratios, short response times, and excellent brightness, driving voltage, and response speed characteristics, and can produce full-color images.

[0003] An organic light-emitting device may include a first electrode disposed (e.g., positioned) on a substrate, and a hole transport region, an emission layer, an electron transport region, and a second electrode, which are sequentially disposed on the first electrode. Holes provided from the first electrode may move toward the emission layer through the hole transport region, and electrons provided from the second electrode may move toward the emission layer through the electron transport region. Carriers, such as the holes and electrons, may then recombine in the emission layer to produce excitons. These excitons change from an excited state to a ground state, thereby generating light.

SUMMARY OF THE INVENTION

[0004] The present invention provides an organic light-emitting device.

[0005] A first aspect of the present invention provides an organic light-emitting device comprising:

- a first electrode;
- a second electrode; and
- an organic layer between the first electrode and the second electrode, the organic layer comprising an emission layer and a hole transport region,

wherein the hole transport region is between the first electrode and the emission layer, and wherein the hole transport region comprises a first compound represented by Formula 1 and a second compound represented by Formula 2:

Formula 1

\[
\begin{align*}
\text{Formula 1} & \\
\begin{align*}
\text{Diagram of Formula 1}
\end{align*}
\end{align*}
\]
In Formulae 1 and 2,

- $X_{11}$ is selected from a single bond, $N(R_{17})$, $P(R_{17})$, $P(R_{17})(R_{18})$, $C(R_{17})(R_{18})$, $Si(R_{17})(R_{18})$, $O$, and $S$;
- $X_{12}$ is selected from a single bond, $N(R_{19})$, $P(R_{19})$, $P(R_{19})(R_{20})$, $C(R_{19})(R_{20})$, $Si(R_{19})(R_{20})$, $O$, and $S$;
- where $X_{11}$ and $X_{12}$ are not both a single bond at the same time;
- $X_{21}$ is selected from $B$, $N$, and $P$;
- $A_{11}$ to $A_{13}$ are each independently selected from a $C_{6}-C_{20}$ cyclic group and a $C_{1}-C_{20}$ heterocyclic group;
- $L_{11}$ to $L_{13}$ and $L_{21}$ to $L_{23}$ are each independently selected from a substituted or unsubstituted $C_{3}-C_{10}$ cycloalkylene group, a substituted or unsubstituted $C_{1}-C_{10}$ heterocycloalkylene group, a substituted or unsubstituted $C_{3}-C_{10}$ cycloalkenylene group, a substituted or unsubstituted $C_{1}-C_{10}$ heterocycloalkenylene group, a substituted or unsubstituted $C_{6}-C_{60}$ arylene group, a substituted or unsubstituted $C_{1}-C_{60}$ heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed $C_{6}-C_{60}$ polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed 8- to 60-membered heteropolycyclic group;
- $a_{11}$ to $a_{13}$ and $a_{21}$ to $a_{23}$ are each independently selected from 0, 1, 2, 3, 4, and 5;
- $R_{11}$ to $R_{13}$ and $R_{21}$ to $R_{23}$ are each independently selected from a substituted or unsubstituted $C_{3}-C_{10}$ cycloalkyl group, a substituted or unsubstituted $C_{1}-C_{10}$ heterocycloalkyl group, a substituted or unsubstituted $C_{3}-C_{10}$ cycloalkenyl group, a substituted or unsubstituted $C_{1}-C_{10}$ heterocycloalkenyl group, a substituted or unsubstituted $C_{6}-C_{60}$ aryl group, a substituted or unsubstituted $C_{1}-C_{60}$ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed $C_{6}-C_{60}$ polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group;
- $R_{14}$ to $R_{16}$ are each independently 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 hydrazogen 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 $C_{1}-C_{60}$ alkoxy group, a substituted or unsubstituted $C_{6}-C_{60}$ aryl group, a substituted or unsubstituted $C_{6}-C_{60}$ arylxy 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 $C_{6}-C_{60}$ polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group;
- $R_{17}$ to $R_{20}$ 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 hydrazogen 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 $C_{1}-C_{60}$ alkoxy group, a substituted or unsubstituted $C_{6}-C_{60}$ aryl group, a substituted or unsubstituted $C_{6}-C_{60}$ arylxy 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 $C_{6}-C_{60}$ polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group;
- $b_{14}$ to $b_{16}$ are each independently selected from 0, 1, 2, 3, and 4; and
- $n_{11}$ to $n_{13}$ are each independently selected from 0, 1, and 2, provided that the sum of $n_{11}$ to $n_{13}$ is selected from 1, 2, 3, 4, 5, and 6.

A second aspect of the present invention provides an organic light-emitting device comprising:
a substrate which is divided according to a first sub-pixel region, a second sub-pixel region, and a third sub-pixel region;
at least one electrode in each of the first sub-pixel region, the second sub-pixel region, and the third sub-pixel region of the substrate, the electrodes in the first, second and third sub-pixel regions together forming a plurality of first electrodes;
a second electrode facing the plurality of first electrodes; and
an organic layer comprising an emission layer and a hole transport region between the second electrode and the plurality of first electrodes,
wherein the hole transport region is between the emission layer and the plurality of first electrodes, and
wherein the hole transport region comprises a first compound represented by Formula 1 and a second compound represented by Formula 2. In the second aspect of the present invention, the first compound represented by Formula 1 and a second compound represented by Formula 2 are the same as described in connection with the first aspect of the present invention.

Brief description of the drawings

[0008] FIG. 1 is a schematic cross-sectional view of an organic light-emitting device according to an embodiment of the present invention.
FIG. 2 is a schematic cross-sectional view of a full-color organic light-emitting device according to an embodiment of the present invention.

Detailed description of the invention

[0009] Advantages and features of the present invention, and how to achieve them, will become more apparent by reference to the embodiments that will be described later in more detail, together with the accompanying drawings. This invention may, however, be embodied in many different forms and should not be limited to the exemplary embodiments described herein.

[0010] Hereinafter, embodiments are described in more detail by referring to the attached drawings, and in the drawings, like reference numerals denote like elements throughout, and thus repeated explanations thereof will not be provided herein.

[0011] As used herein, the singular forms "a," "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.

[0012] It will be further understood that the terms "comprises" and/or "comprising" used herein specify the presence of stated features or components, but do not preclude the presence or addition of one or more other features or components.

[0013] It will be understood that when a layer, region, or component is referred to as being "on" or "onto" another layer, region, or component, it may be directly or indirectly formed on the other layer, region, or component. That is, for example, intervening layers, regions, or components may be present.

[0014] Sizes of components in the drawings may be exaggerated for convenience of explanation. In other words, since sizes and thicknesses of components in the drawings are arbitrarily illustrated for convenience of explanation, the following embodiments are not limited thereto.

[0015] The term "organic layer" used herein may refer to a single layer and/or a plurality of layers disposed between a first electrode and a second electrode of an organic light-emitting device. The "organic layer" may comprise material(s) other than an organic material.

[0016] 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. Further, the use of "may" when describing embodiments of the present invention refers to "one or more embodiments of the present invention."

[0017] FIG. 1 is a schematic view of an organic light-emitting device 10 according to an embodiment of the present disclosure. The organic light-emitting device 10 comprises a first electrode 110, an organic layer 150, and a second electrode 190.

[0018] Hereinafter, the structure of an organic light-emitting device according to an embodiment and a method of manufacturing an organic light-emitting device, according to an embodiment, will be described in connection with FIG. 1.

[0019] In FIG. 1, a substrate may be additionally disposed (e.g., positioned) under the first electrode 110 or above the second electrode 190. The substrate may be a glass substrate or transparent plastic substrate, each with excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and/or water-resistance.
The first electrode 110 may be formed by depositing or sputtering a material for forming the first electrode 110 on the substrate. When the first electrode 110 is an anode, the material for the first electrode 110 may be selected from materials with a high work function so as to facilitate hole injection. The first electrode 110 may be a reflective electrode 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 material include indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO₂), and zinc oxide (ZnO). When the first electrode 110 is a semi-transmissive electrode or a reflective electrode, as a material for forming the first electrode 110, at least one selected from magnesium (Mg), aluminum (Al), aluminum-lithium (Al-Li), calcium (Ca), magnesium-indium (Mg-In), and magnesium-silver (Mg-Ag) may be used.

The first electrode 110 may have a single-layer structure, or a multi-layer structure comprising 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.

The organic layer 150 may be disposed (e.g., positioned) on the first electrode 110. The organic layer 150 comprises an emission layer.

The organic layer 150 further comprises a hole transport region between the first electrode 110 and the emission layer. The organic layer 150 may further comprise an electron transport region disposed between the emission layer and the second electrode 190.

The hole transport region may comprise at least one selected from a hole injection layer, a hole transport layer, a buffer layer; and an electron blocking layer, and the electron transport region may comprise at least one selected from a hole blocking layer, an electron transport layer, and an electron injection layer; but they are not limited thereto.

The hole transport region may have a single-layered structure consisting of a single material, a single-layered structure comprising a plurality of different materials, or a multi-layered structure having a plurality of layers formed of a plurality of different materials.

For example, the hole transport region may have a single-layered structure comprising a plurality of different materials, or a multi-layered structure having a plurality of layers formed of a plurality of different materials.

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

When a hole injection layer is formed by vacuum deposition, for example, the vacuum deposition may be performed at a deposition temperature of about 100 to about 500°C, at a vacuum degree of about 10⁻⁸ to about 10⁻³ torr, and at a deposition rate of about 0.01 to about 100 Å/sec, by taking into account a compound for the hole injection layer to be deposited and the structure of the hole injection layer to be formed.

When a hole injection layer is formed by spin coating, for example, the spin coating may be performed at a coating rate of about 2000 rpm to about 5000 rpm and at a temperature of about 80°C to 200°C, by taking into account a compound for the hole injection layer to be deposited and the structure of the hole injection layer to be formed.

When the hole transport region comprises a hole transport layer, the hole transport layer may be formed on the first electrode 110 or the hole injection layer by using one or more 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, deposition and coating conditions for the hole transport layer may be the same as or similar to the deposition and coating conditions for the hole injection layer.

The hole transport region comprises a first compound represented by Formula 1 and a second compound represented by Formula 2:
In Formula 1, X_{11} is selected from N(R_{17}), P(R_{17}), P(R_{17})(R_{18}), C(R_{17})(R_{18}), Si(R_{17})(R_{18}), O, and S, and R_{17} and R_{18} are as described below.

For example, X_{11} in Formula 1 may be selected from N(R_{17}), C(R_{17})(R_{18}), O, and S, but is not limited thereto.

X_{12} in Formula 1 may be selected from a single bond, N(R_{19}), P(R_{19}), P(R_{19})(R_{20}), C(R_{19})(R_{20}), Si(R_{19})(R_{20}), O, and S, and R_{19} and R_{20} are as described below.

For example, X_{12} in Formula 1 may be a single bond, but is not limited thereto.

X_{21} in Formula 2 is selected from B, N, and P.

For example, X_{21} in Formula 2 may be N, but is not limited thereto.

A_{11} to A_{13} in Formula 1 are each independently selected from a C_{5}-C_{20} cyclic group and a C_{1}-C_{20} heterocyclic group.

For example, A_{11} to A_{13} in Formula 1 may be each independently selected from a benzene, a naphthalene, a fluorene, a phenanthrene, an anthracene, a triphenylene, a pyrene, a chrysene, a furan, a thiophene, a pyrrole, a pyridine, a pyrazine, a pyridazine, a quinoline, an isoquinoline, a quinonoline, a quinoxaline, a benzofuran, a benzoquinoxaline, a dibenzofuran, a dibenzoquinoxaline, and a carbazole, but are not limited thereto.

In some embodiments, A_{11} to A_{13} in Formula 1 may be each independently selected from a benzene, a naphthalene, a fluorene, a phenanthrene, an anthracene, a pyridine, a quinoline, an isoquinoline, and a carbazole, but are not limited thereto.

In some embodiments, A_{11} and A_{12} in Formula 1 may be each independently selected from a benzene and a naphthalene; and

A_{13} may be selected from a benzene, a naphthalene, and a pyridine, but are not limited thereto.

In some embodiments, A_{11} to A_{13} in Formula 1 may be each independently selected from a benzene and a naphthalene, but are not limited thereto.

In some embodiments, A_{11} to A_{13} in Formula 1 may be a benzene, but are not limited thereto.
[0045] L11 to L13 and L21 to L23 in Formulae 1 and 2 are each independently selected from a substituted or unsubstituted C2-C10 cycloalkylene group, a substituted or unsubstituted C1-C10 heterocycloalkylene group, a substituted or unsubstituted C2-C10 cycloalkenylene group, a substituted or unsubstituted C1-C10 heterocycloalkenylene group, a substituted or unsubstituted C2-C80 arylene group, a substituted or unsubstituted C1-C80 heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed C8-C80 poly cyclic group, and a substituted or unsubstituted divalent non-aromatic condensed 8- to 60-membered heteropolycyclic group.

[0046] For example, L11 to L13 and L21 to L23 in Formulae 1 and 2 may be each independently selected from a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an indacenyl group, an acenaphthenylene group, a fluoranthenylene group, an imidazolylene group, a pyrazolylene group, a thiadiazolyl group, and an imidazopyridinyl group, but are not limited thereto.

[0047] In some embodiments, L11 to L13 and L21 to L23 in Formulae 1 and 2 may be each independently selected from a phenylene group, a fluorenylene group, a phenanthrenylene group, an anthracenylene group, a dibenzofluorenylene group, a dibenzocarbazolyl group, a thiadiazolyl group, and an imidazopyridinyl group, but are not limited thereto.
a triphenylenylene group, a pyrrolylene group, a thiophenylene group, a furanylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, an indolylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a carbazolylene group, a phenanthridinylene group, a benzoimidazolylene group, a benzofuranylene group, a benzothiophenylene group, a triazolylene group, a dibenzofuranylene group, and a dibenzothiophenylene group; and a phenylene group, a naphthylene group, a fluorenylene group, a phenanthrenylene group, an anthracenylene group, a triphenylenylene group, a pyrrolylene group, a thiophenylene group, a furanylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, an indolylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a carbazolylene group, a phenanthridinylene group, a benzoimidazolylene group, a benzofuranylene group, a benzothiophenylene group, a triazolylene group, a dibenzofuranylene group, and a dibenzothiophenylene 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 hydrazono group, a carboxyl group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁₋C₂₀ alkyl group, a C₁₋C₂₀ alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-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 are not limited thereto.

In some embodiments, L₁₁ to L₁₃ and L₂₁ to L₂₃ in Formulae 1 and 2 may be each independently a group represented by any one of Formulae 3-1 to 3-19, but are not limited thereto:

**[0048]** In some embodiments, L₁₁ to L₁₃ and L₂₁ to L₂₃ in Formulae 1 and 2 may be each independently a group represented by any one of Formulae 3-1 to 3-19, but are not limited thereto:

[0049] In Formulae 3-1 to 3-19,

$X_{31}$ may be selected from O, S, and C(R₃₃)(R₃₄);

R₃₁ to R₃₅ may be each independently 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 hydrazono group, a carboxyl group or a salt thereof.
thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₃₋₁₅ alkyl group, a
C₁₋₅ alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzo-fluorenyl
group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group,
a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl
group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;
R₃₃ to R₃₄ may be each independently selected from hydrogen, deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano
or a nitro group, an amidino group, a hydrazine group, a carbonyl group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁₋₅ alkyl group, a C₁₋₅ alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzo-fluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;
a₃₁ may be selected from o, 1, 2, 3, and 4;
a₃₂ may be selected from o, 1, 2, 3, 4, 5, and 6;
a₃₃ may be selected from o, 1, 2, 3, 4, 5, 6, 7, and 8;
a₃₄ may be selected from o, 1, 2, 3, 4, and 5;
a₃₅ may be selected from o, 1, 2, and 3; and
* and *' may be each independently a binding site to a neighboring atom.
a₁₁ in Formula 1 indicates the number of L₁₁(s), and a₁₁ is selected from o, 1, 2, 3, 4, and 5. When a₁₁ is o, (L₁₁)ₐ₁₁
is a single bond. When a₁₁ is 2 or more, a plurality of L₁₁(s) may be identical to or different from each other.
a₁₂, a₁₃ and a₂₁ to a₂₃ in Formulæ 1 and 2 are as defined herein for a₁₁ and corresponding formulæ. a₁₂, a₁₃
and a₂₁ to a₂₃ in Formulæ 1 and 2 are each independently selected from o, 1, 2, 3, 4, and 5.

For example, a₁₁ to a₁₃ and a₂₁ to a₂₃ in Formulæ 1 and 2 may be each independently selected from o, 1, and
2, but are not limited thereto.

For example, (L₁₁)ₐ₁₁, (L₁₂)ₐ₁₂, (L₁₃)ₐ₁₃, (L₂₁)ₐ₂₁, (L₂₂)ₐ₂₂ and (L₂₃)ₐ₂₃ in Formulæ 1 and 2 may be each
independently a group represented by any one of Formulæ 4-1 to 4-14, but are not limited thereto:

In Formulæ 4-1 to 4-14,
* and *' may be each independently a binding site to a neighboring atom.
R₁₁ to R₁₃ and R₂₁ to R₂₃ in Formulæ 1 and 2 are each independently selected from a substituted or unsubstituted
C_{3-10} cycloalkyl group, a substituted or unsubstituted C_{1-10} heterocycloalkyl group, a substituted or unsubstituted C_{3-10} cycloalkenyl group, a substituted or unsubstituted C_{1-10} heterocycloalkenyl group, a substituted or unsubstituted C_{8-60} aryl group, a substituted or unsubstituted C_{1-60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed C_{2-60} polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group.

[0054] For example, R_{11} to R_{13} and R_{21} to R_{23} in Formulae 1 and 2 may be each independently selected from a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indaceny group, an acenaphthy group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, a fluorantheny group, a triphenylenyl group, a pyrenyl group, a chryseny group, a naphthaceny group, a piceny group, a perylenyl group, a pentapheny group, a hexaceny group, a pentacenyl group, a rubiceny group, a coroneny group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazoly 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 carbazolyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, a quinazolinyl group, a benzoquinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a benzofuranyl group, an isobenzofuranyl group, a benzothiophenyl group, an isobenzothiophenyl group, an isothiophenyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzothiophenyl group, a phenalenyl group, a phenanthrenyl group, a phenoxathinyl group, and a dibenzodioxinyl group; and

and a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indaceny group, an acenaphthy group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluorantheny group, a triphenylenyl group, a pyrenyl group, a chryseny group, a naphthaceny group, a piceny group, a perylenyl group, a pentapheny group, a hexaceny group, a pentacenyl group, a rubiceny group, a coroneny group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazoly 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 carbazolyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a benzoquinoxalinyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, a thianthrenyl group, a phenoxathinyl group, and a dibenzodioxinyl group; and

transport group, but are not limited thereto.

[0055] In some embodiments, R_{11} to R_{13} and R_{21} to R_{23} in Formulae 1 and 2 may be each independently a hole transport group, but are not limited thereto.
In some embodiments, R11 to R13 and R21 to R23 in Formulae 1 and 2 may be each independently selected from 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 fluorantheny group, a triphenylenyl group, a pyrenyl group, a chrysene group, a naphthacencyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzothiophenyl group, a dibenzocarbazolyl group, a thianthrenyl group, a phenoxathinyl group, and a dibenzodioxinyl group; and

a phenyl group, a pentalenyl group, an indenyl group, a naphthyl 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 fluorantheny group, a triphenylenyl group, a pyrenyl group, a chrysene group, a naphthacencyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzothiophenyl group, a dibenzocarbazolyl group, a thianthrenyl group, a phenoxathinyl group, and a dibenzodioxinyl group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C1-C20 alkyl group, a C1-C20 alkoxy group, a phenyl group, a naphthyl group, a spiro-fluorenyl group, and a carboxyl group, but are not limited thereto.

In some embodiments, R11 to R13 and R21 to R23 in Formulae 1 and 2 may be each independently selected from a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a phenanthrenyl group, an anthracenyl group, a triphenylenyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzothiophenyl group, a thianthrenyl group, a phenoxathinyl group, a dibenzodioxinyl group; and

a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a phenanthrenyl group, an anthracenyl group, a triphenylenyl group, a carbazolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzothiophenyl group, a thianthrenyl group, a phenoxathinyl group, and a dibenzodioxinyl group, each substituted with at least one selected from deuterium, a cyano group, a C1-C20 alkyl group, a C1-C20 alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, and a carbazolyl group, but are not limited thereto.

In some embodiments, R11 to R13 and R21 to R23 in Formulae 1 and 2 may be each independently selected from groups represented by Formulae 5-1 to 5-12, but are not limited thereto:
In Formulae 5-1 to 5-12,

$X_{51}$ may be selected from a single bond, $N(R_{54})$, $C(R_{54})$, $O$, and $S$;

$X_{52}$ may be selected from $N(R_{56})$, $C(R_{56})$, $O$, and $S$;

$R_5$ to $R_{57}$ may be each independently selected from deuterium, a cyano group, a C$_1$-C$_{20}$ alkyl group, a phenyl group, a naphthyl group, a fluorenyl group, and a carbazolyl group; and $R_{54}$ and $R_{55}$ may optionally bind to each other to form a ring;

$b_{51}$ may be selected from 1, 2, 3, 4, and 5;

$b_{52}$ may be selected from 1, 2, 3, 4, 5, 6, and 7;

$b_{53}$ may be selected from 1, 2, and 3;

$b_{54}$ may be selected from 1, 2, 3, 4, and 5;

$b_{55}$ may be selected from 1, 2, 3, 4, 5, and 6; and

* indicates a binding site to a neighboring atom.

In embodiments where $R_{54}$ and $R_{55}$ combine to form a ring, the ring is typically selected from a substituted or unsubstituted C$_3$-C$_{10}$ cycloalkyl group, a substituted or unsubstituted C$_1$-C$_{10}$ heterocycloalkyl group, a substituted or unsubstituted C$_3$-C$_{10}$ cycloalkenyl group, a substituted or unsubstituted C$_1$-C$_{10}$ heterocycloalkenyl group, a substituted or unsubstituted C$_6$-C$_{60}$ aryl group, a substituted or unsubstituted C$_1$-C$_{60}$ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed C$_8$-C$_{60}$ polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group. The ring is preferably a substituted or unsubstituted monovalent non-aromatic condensed C$_8$-C$_{60}$ polycyclic group, e.g. a substituted or unsubstituted fluorenyl group.

In some embodiments, $R_{11}$ to $R_{13}$ and $R_{21}$ to $R_{23}$ in Formulae 1 and 2 may be each independently selected from groups represented by Formulae 6-1 to 6-49, but are not limited thereto:
In Formulae 6-1 to 6-49, Ph may refer to a phenyl group; and
* indicates a binding site to a neighboring atom.

R_{14} to R_{16} in Formulae 1 and 2 are each independently selected from deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazine group, a 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_1-C_{60} alkoxy group, a substituted or unsubstituted C_1-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} aryl 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 C_8-C_{60} polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group.

For example, R_{14} to R_{16} in Formulae 1 and 2 may be each independently selected from deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazine group, a 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_1-C_{60} alkoxy group, a C_6-C_{60} aryl group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed C_8-C_{60} polycyclic group, and a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group, and -Si(Q_1)(Q_2)(Q_3); and

Q_1 to Q_3 may be each independently selected from a C_1-C_{60} alkyl group and a C_6-C_{60} aryl group, but are not limited thereto.

In some embodiments, R_{14} to R_{16} in Formulae 1 and 2 may be each independently selected from a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, isobutyl group, a sec-butyl group, a tert-butyl group, a phenyl group, a naphthyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, but are not limited thereto.

b_{14} in Formula 1 indicates the number of R_{14}(s), and b_{14} is selected from o, 1, 2, 3, and 4. When b_{14} is 2 or
more, a plurality of R_{14}(s) may be identical to or different from each other.

[0067] b15 in Formula 1 indicates the number of R_{15}(s), and b15 is selected from 0, 1, 2, 3, and 4. When b15 is 2 or more, a plurality of R_{15}(s) may be identical to or different from each other.

[0068] b16 in Formula 1 indicates the number of R_{16}(s), and b16 is selected from 0, 1, 2, 3, and 4. When b16 is 2 or more, a plurality of R_{16}(s) may be identical to or different from each other.

[0069] R_{17} to R_{20} in Formulae 1 and 2 are each independently selected from hydrogen, deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazine group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a substituted or unsubstituted C_{1-60} alkyl group, a substituted or unsubstituted C_{1-60} alkoxy group, a substituted or unsubstituted C_{6-60} aryl group, a substituted or unsubstituted C_{6-60} aryloxy group, a substituted or unsubstituted C_{6-60} arylthio group, a substituted or unsubstituted C_{1-60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed C_{2-60} polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group.

[0070] For example, R_{17} to R_{20} in Formulae 1 and 2 may be each independently selected from hydrogen, deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_{1-60} alkyl group, a C_{1-60} alkoxy group, a C_{6-60} aryl group, a C_{1-60} heteroaryl group, a monovalent non-aromatic condensed C_{2-60} polycyclic group, and a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group, and -Si(Q_{1})(Q_{2})(Q_{3}); and

Q_{1} to Q_{3} may be each independently selected from a C_{1-60} alkyl group and a C_{6-60} aryl group, but are not limited thereto.

[0071] In some embodiments, R_{17} to R_{20} in Formulae 1 and 2 may be each independently selected from a C_{1-60} alkyl group, a C_{6-60} aryl group, a monovalent non-aromatic condensed C_{2-60} polycyclic group, and a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group, but are not limited thereto.

[0072] In some embodiments, R_{17} to R_{20} in Formulae 1 and 2 may be each independently selected from a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, iso-butyl group, a sec-butyl group, a tert-butyl group, a phenyl group, a naphthyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, but are not limited thereto.

[0073] n11 in Formula 1 indicates the number of groups represented by -(L_{11})_{a11}R_{11}, and n11 is selected from 0, 1, and 2. When n11 is 2, two groups represented by -(L_{11})_{a11}R_{11} may be identical to or different from each other.

[0074] n12 in Formula 1 indicates the number of groups represented by -(L_{12})_{a12}R_{12}, and n12 is selected from 0, 1, and 2. When n12 is 2, two groups represented by -(L_{12})_{a12}R_{12} may be identical to or different from each other.

[0075] n13 in Formula 1 indicates the number of groups represented by -(L_{13})_{a13}R_{13}, and n13 is selected from 0, 1, and 2. When n13 is 2, two groups represented by -(L_{13})_{a13}R_{13} may be identical to or different from each other.

[0076] The sum of n11 to n13 in Formula 1 is selected from 1, 2, 3, 4, 5, and 6.

[0077] For example, n11 to n13 in Formula 1 may be selected from 0 and 1, provided that the sum of n11 to n13 is selected from 1 and 2, but they are not limited thereto.

[0078] In some embodiments, n11 to n13 in Formula 1 are each independently selected from 0 and 1, provided that the sum of n11 to n13 is 1, but they are not limited thereto.

[0079] In some embodiments, the first compound represented by Formula 1 may be represented by one of Formulae 1-1 to 1-3, but is not limited thereto.
In Formulae 1-1 to 1-3, $X_{11}$ may be selected from N(R$_{17}$), P(R$_{17}$), P(R$_{17}$(R$_{18}$), C(R$_{17}$(R$_{18}$), Si(R$_{17}$)(R$_{18}$), O, and S; and $A_{11}$ to $A_{13}$, L$_{11}$ to L$_{13}$; a$_{11}$ to a$_{13}$, R$_{11}$ to R$_{13}$, R$_{14}$ to R$_{16}$, and b$_{14}$ to b$_{16}$ may be the same as described herein in connection with Formula 1.

For example, $A_{11}$ to $A_{13}$ in Formulae 1-1 to 1-3 may be each independently selected from a benzene and a naphthalene, but are not limited thereto.

In some embodiments, in Formulae 1-1 to 1-3, $A_{11}$ and $A_{12}$ may be a benzene, and $A_{13}$ may be a naphthalene; in some embodiments, each of $A_{12}$ and $A_{13}$ may be a benzene, and $A_{11}$ may be a naphthalene; and in some embodiments, each of $A_{13}$ and $A_{11}$ may be a benzene, and $A_{12}$ may be a naphthalene, but are not limited thereto.

In some embodiments, $A_{11}$ to $A_{13}$ in Formulae 1-1 to 1-3 may each be a benzene, but are not limited thereto.

In some embodiments, the compound represented by Formula 1 may be represented by one of Formulae 1-11 to 1-13, but is not limited thereto:
In Formulae 1-11 to 1-13, X11 may be selected from N(R17), P(R17), P(R(R17)(R18), C(R17)(R18), Si(R17)(R18), O, and S; and A11 to A13, L11 to L13, a11 to a13, R11 to R13, R14 to R18 and b14 to b16 may be the same as described herein in connection with Formula 1.

In some embodiments, the compound represented by Formula 1 may be represented by any one of Formulae 1-21 to 1-31, but is not limited thereto:
In Formulae 1-21 to 1-31, X_{11} may be selected from N(R_{17}), P(R_{17}), C(R_{17})(R_{18}), Si(R_{17})(R_{18}), O, and S; and A_{11} to A_{13}, L_{11} to L_{13}, a_{11} to a_{13}, R_{11} to R_{13}, R_{14} to R_{18}, and b_{14} to b_{16} may be the same as described herein in connection with Formula 1.

For example, A_{11} to A_{13} in Formulae 1-21 to 1-31 may each be a benzene, but are not limited thereto.

In some embodiments, the compound represented by Formula 1 may be selected from Compounds A_{1} to A_{52}, but is not limited thereto:
A13
A14
A15
A16
A17
A18
A19
A20
A21
A22
A23
A24
A25
A26
A27
A28
In some embodiments, the second compound represented by Formula 2 may be represented by Formula 2-1, but is not limited thereto:

**Formula 2-1**

In Formula 2-1,

- \(X_{21}, L_{21}, L_{22}, L_{23}, a_{21}, a_{22}, a_{23}, R_{22}, R_{23}\) may be the same as described herein in connection with Formula 2;
- \(R_{201}\) to \(R_{204}\) may be each independently 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 substituted or unsubstituted \(C_{1-60}\) alkyl group, a substituted or unsubstituted \(C_{1-60}\) alkoxy group, a substituted or unsubstituted \(C_{6-60}\) aryl group, a substituted or unsubstituted \(C_{6-60}\) aryloxy group, a substituted or unsubstituted \(C_{1-60}\) arylthio group, a substituted or unsubstituted \(C_{1-60}\) heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed \(C_{8-60}\) polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group;
- \(R_{203}\) to \(R_{204}\) may be 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 \(C_{1-60}\) alkyl group, a substituted or unsubstituted \(C_{1-60}\) alkoxy group, a substituted or unsubstituted \(C_{6-60}\) aryl group, a substituted or unsubstituted \(C_{6-60}\) aryloxy group, a substituted or unsubstituted \(C_{6-60}\) arylthio group, a substituted or unsubstituted \(C_{1-60}\) heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed \(C_{8-60}\) polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group;

- \(b_{201}\) may be selected from 0, 1, 2, and 3; and
- \(b_{202}\) may be selected from 0, 1, 2, 3, and 4.
In some embodiments, the second compound represented by Formula 2 may be represented by Formula 2-11, but is not limited thereto:

**Formula 2-11**

In Formula 2-11,

- $X_{21}$, $L_{21}$ to $L_{23}$, $a_{21}$ to $a_{23}$, and $R_{22}$ may be the same as described herein in connection with Formula 2;
- $X_{22}$ may be selected from N(R$_{203}$), O, and S;
- $R_{201}$ to $R_{202}$ may be each independently 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 substituted or unsubstituted C$_1$-C$_{60}$ alkyl group, a substituted or unsubstituted C$_1$-C$_{60}$ alkoxy 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 8- to 60-membered heteropolycyclic group;
- $R_{203}$, $R_{205}$, and $R_{206}$ may be 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$_1$-C$_{60}$ alkoxy 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 8- to 60-membered heteropolycyclic group;
- $b_{201}$ may be selected from 0, 1, 2, and 3; and
- $b_{202}$ may be selected from 0, 1, 2, 3, and 4.

In some embodiments, the second compound represented by Formula 2 may be represented by any one of Formulae 2-21 to 2-36, but is not limited thereto:
In Formulae 2-21 to 2-36, X$_{21}$, L$_{21}$ to L$_{23}$, a$_{21}$ to a$_{23}$, and R$_{22}$ may be the same as described herein in connection with Formula 2; X$_{22}$ may be selected from N(R$_{203}$), O, and S; R$_{201}$ to R$_{202}$ may be each independently 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 substituted or unsubstituted C$_1$-C$_{60}$ alkyl group, a substituted or unsubstituted C$_1$-C$_6$ alkoxy group, a substituted or unsubstituted C$_6$-C$_{60}$ aryl group, a substituted or unsubstituted C$_6$-C$_{60}$ arylxy group, a substituted or unsubstituted C$_6$-C$_{60}$ arythio...
group, a substituted or unsubstituted C$_{1}$-C$_{60}$ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed C$_{6}$-C$_{60}$ polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group;

$R_{203}$, $R_{205}$, and $R_{206}$ may be 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$_{1}$-C$_{60}$ alkoxy 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 C$_{6}$-C$_{60}$ polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group;

$b_{201}$ may be selected from 0, 1, 2, and 3; and

$b_{202}$ may be selected from 0, 1, 2, 3, and 4.

[0096] In some embodiments, the second compound represented by Formula 2 may be represented by one of Formulae 2-41 to 2-44, but is not limited thereto:
In Formulae 2-41 to 2-44,

\[ X_{21}, L_{21}, L_{23}, a_{21}, a_{23}, \text{and } R_{22} \text{ may be the same as described herein in connection with Formula 2; } \]
\[ X_{22} \text{ may be selected from } N(R_{203}), O, \text{and } S; \]
\[ R_{201} \text{ to } R_{202} \text{ may be each independently selected from deuterium, } -F, -Cl, -Br, -I, \text{a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a substituted or unsubstituted } C_1-C_{60} \text{ alkyl group, a substituted or unsubstituted } C_1-C_{60} \text{ alkoxy group, a substituted or unsubstituted } C_1-C_{60} \text{ aryl group, a substituted or unsubstituted } C_1-C_{60} \text{ aryloxy group, a substituted or unsubstituted } C_1-C_{60} \text{ arylthio group, a substituted or unsubstituted monovalent non-aromatic condensed } C_1-C_{60} \text{ polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group; } \]
\[ R_{203}, R_{205}, \text{and } R_{206} \text{ may be each independently selected from hydrogen, deuterium, } -F, -Cl, -Br, -I, \text{a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a substituted or unsubstituted } C_1-C_{60} \text{ alkyl group, a substituted or unsubstituted } C_1-C_{60} \text{ alkoxy group, a substituted or unsubstituted } C_1-C_{60} \text{ aryl group, a substituted or unsubstituted } C_1-C_{60} \text{ aryloxy group, a substituted or unsubstituted } C_1-C_{60} \text{ arylthio group, a substituted or unsubstituted monovalent non-aromatic condensed } C_1-C_{60} \text{ polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group; } \]
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 C$_8$-C$_{60}$ polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group; b201 may be selected from 0, 1, 2, and 3; and b202 may be selected from 0, 1, 2, 3, and 4.

[0098] In some embodiments, the second compound represented by Formula 2 may be selected from Compounds H-01 to H-36, but is not limited thereto:
When an organic light-emitting device comprises an electron transport region in which electrons move relatively slowly, light may be emitted from a portion of an emission layer that is closer to an interface between the emission layer
and the electron transport region than the remaining portion of the emission layer. Accordingly, due to excess holes provided to the electron transport region, the electron transport region may be damaged, leading to a decrease in the lifespan of the organic light-emitting device.

On the other hand, when an organic light-emitting device comprises an electron transport region in which electrons move relatively quickly, light may be emitted from a portion of an emission layer that is closer to an interface between the emission layer and the hole transport region than the remaining portion of the emission layer. Accordingly, due to excess electrons provided to the hole transport region, the hole transport region may be damaged, leading to a short lifespan of the organic light-emitting device.

However, when the hole transport region of the organic light-emitting device comprises one or more layers, holes and electrons may be easily balanced in the organic light-emitting device, leading to an increase in the efficiency and lifespan of the organic light-emitting device.

The compound represented by Formula 1 may have a high electron resisting capability, and may not be substantially deteriorated by electrons, and the second compound represented by Formula 2 may easily control a charge balance. Accordingly, when the compound of Formula 1 is used in a layer constituting the hole transport region that is near the emission layer and the compound of Formula 2 is used in a layer constituting the hole transport region that is far from the emission layer, the efficiency and lifespan of the organic light-emitting device may be increased.

The hole transport region may further comprise, in addition to the first compound represented by Formula 1 and the second compound represented by Formula 2, at least one selected from m-MTDATA, TDATA, 2-TNATA, NPB, β-NPB, TPD, Spiro-TPD, Spiro-NPB, methylated-NPB, TAPC, HMTPD, DNTPD, 4,4',4"-tris(N-carbazolyl)triphenylamine (TCTA), polyaniline/dodecybenzenesulfonic acid (Pani/DBSA), poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate) (PEDOT/PSS), polyaniline/camphor sulfonicacid (Pani/CSA), (polyaniline)/poly(4-styrenesulfonate) (PANI/PSS), and a compound represented by Formula 202 below:
In Formula 202,

L₁ to L₅ are each independently as defined herein for L₁₁;
xa₁ to xa₄ may be each independently selected from 0, 1, 2, and 3;
xa₅ may be selected from 1, 2, 3, 4, and 5; and
R₉₀₁ to Rₙ₀₄ are each independently as defined herein for R₁₁.

The compound represented by Formula 202 may be represented by Formula 202A, but is not limited thereto:

xa₅, R₂₀₂ and R₂₀₄ in Formula 202A may be the same as described above, R₂₁₁ and R₂₁₂ may be each independently the same as described herein in connection with R₁₁, and R₂₁₅ and R₂₁₆ may be each independently the same as described herein in connection with R₁₄.

The compound represented by Formula 202 may be selected from Compounds HT₁₃ to HT₂₀, but is not limited thereto:
The hole transport region may comprise a first layer and a second layer; and the second layer may be disposed (e.g., positioned) between the first layer and a first electrode. The first layer may comprise the first compound according to embodiments of the present disclosure, and the second layer may comprise the second compound according to embodiments of the present disclosure.

A thickness of the hole transport region may be in a range of about 50Å to about 10,000Å, for example, about 150Å or more, about 2000Å or less, or about 1500Å or less. When the hole transport region comprises the first layer and the second layer, a thickness of the second layer may be in a range of about 50Å to about 600Å.
layer, a thickness of the first layer may be in a range of about 50 Å to about 2000 Å, for example, about 100 Å to about 1500 Å. When the thicknesses of the hole transport region, the first layer, and the second layer are within any of these ranges, suitable hole transporting characteristics may be obtained without in a substantial increase in driving voltage.

[0109] The hole transport region may further comprise, in addition to the materials described above, a charge-generation material for the improvement of conductive properties. The charge-generation material may be homogeneously or unhomogeneously dispersed in the hole transport region. For example, the charge-generation material may be present at a high concentration in a portion of the hole transport region that is near the first electrode. In some embodiments, the charge-generation material may be present in a high concentration in a portion of the hole transport region that is near the emission layer.

[0110] The charge-generation material may be, for example, a p-dopant. The p-dopant may be one selected from a quinone derivative, a metal oxide, and a cyano group-containing compound, but embodiments are not limited thereto. Non-limiting examples of the p-dopant include quinone derivatives (such as tetracyanoquinonedimethane (TCNQ) and/or 2,3,5,6-tetrafluoro-tetracyano-1,4-benzoquinonedimethane (F4-TCNQ)); metal oxides (such as tungsten oxide and/or molybdenum oxide), 2-(7-dicyanomethylene-1,3,4,5,6,8,9,10-octafluoro-7H-pyrene-2-yiIdene)-malonitrile, and Compound HT-D1 illustrated below.

![Compound HT-D1](image1)

![F4-TCNQ](image2)

[0111] The hole transport region may further comprise, in addition to the hole injection layer and the hole transport layer, at least one selected from a buffer layer and an electron blocking layer. Since the buffer layer may compensate for an optical resonance distance according to a wavelength of light emitted from the emission layer, light-emission efficiency of the formed organic light-emitting device may be improved. For use as a material comprised in the buffer layer, any of the materials that are comprised in the hole transport region may be used. The electron blocking layer may prevent or reduce the injection of electrons from the electron transport region.

[0112] An emission layer may be formed on the first electrode 110 or the hole transport region by using one or more methods selected from vacuum deposition, spin coating, casting, an LB method, ink-jet printing, laser-printing, and laser-induced thermal imaging. When an emission layer is formed by vacuum deposition and/or spin coating, deposition and coating conditions for the emission layer may be the same as or similar to those for the hole injection layer.

[0113] When the organic light-emitting device 10 is a full color organic light-emitting device, the emission layer may be patterned into a red emission layer, a green emission layer, or a blue emission layer, according to a sub-pixel. In some embodiments, the emission layer may have a stacked structure of a red emission layer, a green emission layer, and a blue emission layer, or may comprise a red-light emission material, a green-light emission material, and a blue-light emission material, which are mixed with each other in a single layer, to emit white light. In some embodiments, the emission layer may be a white emission layer, and may further comprise a color converting layer or a color filter to turn white light into light of a desired color.

[0114] The emission layer may comprise a host and a dopant.

[0115] The host may comprise at least one selected from TPBi, TBADN, ADN, CBP, CDBP, and TCP:
In some embodiments, the host may comprise a compound represented by Formula 301 below.

**Formula 301**

$$\text{Ar}_{201}^\text{L}-\left(\text{R}_{201}\right)_{x2}-\text{R}_{301}^\text{L}.$$ 

In Formula 301,\n\n- \(\text{Ar}_{201}\) may be selected from a naphthalene, a heptalene, a fluorene, a spiro-fluorene, a benzofluorene, a dibenzofluorene, a phenalene, a phenanthrene, an anthracene, a fluoranthenne, a triphenylene, a pyrene, a chrysene, a naphthacene, a picene, a perylene, a pentaphene, and an indenoanthracene;
- \(\text{Ar}_{201}\) may be selected from a naphthalene, a heptalene, a fluorene, a spiro-fluorene, a benzofluorene, a dibenzofluorene, a phenalene, a phenanthrene, an anthracene, a fluoranthenne, 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 C1-C20 alkyl group, a C2-C60 alkenyl group, a C1-C60 alkoxyl group, a C1-C60 alkoxy group, a C2-C60 alkyl group, a C2-C60 alkenyl group, a C2-C60 alkynyl group, a C1-C60 alkoxy group, a C3-C10 cycloalkyl group, a C1-C60 heterocycloalkyl group, a C2-C60 aryl group, 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 C1-C20 alkyl group, a C2-C60 alkenyl group, a C6-C60 aryloxy group, a C1-C60 heteroaryl group, a monovalent non-aromatic condensed C6-C60 polycyclic group, a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group, and -Si(\(Q_{301}\))(\(Q_{302}\))(\(Q_{303}\)) (where \(Q_{301}\) to \(Q_{303}\) may be each independently selected from hydrogen, a C1-C60 alkyl group, a C2-C60 alkenyl group, a C6-C60 aryloxy group, and a C1-C60 heteroaryl group);
- L301 is as defined herein for L201;
- R301 may be selected from:
  - a C1-C20 alkyl group and a C1-C20 alkoxy group;
  - a C1-C20 alkyl group and a C1-C20 alkoxy group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, 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 naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolyl group, a carbazolyl group, and a triazinyl 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 pyrene group, a chrysene group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolyl 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 pyrene group, a chrysene 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 C1-C20 alkyl group, a C1-C20 alkoxy group, a phenyl group, a
napthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a
phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysene group, a pyrazinyl group, a pyridinyl group,
a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group,
a carbazolyl group, and a triazinyl group;

xb1 may be selected from 0, 1, 2, and 3; and
xb2 may be selected from 1, 2, 3, and 4.

[0118] In Formula 301, L301 may be selected from:

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, and
a chrysenylene 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, and
a chrysenylene group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, a hydroxyl group,
a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic
acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C1-C20
alkyl group, a C1-C20 alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a
benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, and
a chrysenyl group;

R301 may be selected from:

a C1-C20 alkyl group and a C1-C20 alkoxy group;
a C1-C20 alkyl group and a C1-C20 alkoxy group, each substituted with at least one selected from deuterium, -F, -Cl,
-Br, -I, a hydroxyl group, a cyano group, 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 naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl
group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, and a chrysenyl
group;
a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzoflu-
oarenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, and a chrysenyl group; and

[0119] The compound represented by Formula 301 may comprise at least one of Compounds H1 to H42 (where "D"
may refer to deuterium), but is not limited thereto:
In some embodiments, the host may comprise at least one of Compounds H\textsubscript{43} to H\textsubscript{49} below, but is not limited thereto:
The dopant may comprise at least one selected from a fluorescent dopant and a phosphorescent dopant.

The phosphorescent dopant may comprise an organometallic complex represented by Formula 401 below:

In Formula 401, M may be selected from iridium (Ir), platinum (Pt), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), and thulium (Tm);

X₄₀₁ to X₄₀₄ may be each independently nitrogen or carbon;

A₄₀₁ and A₄₀₂ rings may be each independently selected from a substituted or unsubstituted benzene, a substituted or unsubstituted naphthalene, a substituted or unsubstituted fluorene, a substituted or unsubstituted spiro-fluorene, a substituted or unsubstituted indene, a substituted or unsubstituted pyrrole, a substituted or unsubstituted thiophene, a substituted or unsubstituted furan, a substituted or unsubstituted imidazole, a substituted or unsubstituted pyrazole, a
In Formula 401, L 401 may be a monovalent, divalent, or trivalent organic ligand. For example, L 401 may be Q401 to Q407, Q411 to Q417, and Q421 to Q427 may be each independently selected from hydrogen, a C1-C60 alkyl group, a C2-C60 alkenyl group, a C2-C60 alkynyl group, a C1-C60 alkoxy group, a C3-C10 cycloalkyl group, a C1-C10 heterocycloalkyl group, a C3-C10 cycloalkenyl group, a C1-C10 heterocycloalkenyl group, a C6-C60 aryl group, a C6-C60 aryloxy group, a C6-C60 arylthio group, a C1-C60 heteroaryl group, a monovalent non-aromatic condensed C8-C60 polycyclic group, a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic groups, -N(Q401)(Q402), -Si(Q403)(Q404)(Q405), and -B(Q406)(Q407); a C3-C10 cycloalkyl group, a C1-C10 heterocycloalkyl group, a C3-C10 cycloalkenyl group, a C1-C10 heterocycloalkenyl group, a C6-C60 aryl group, a C6-C60 aryloxy group, a C6-C60 arylthio group, a C1-C60 heteroaryl group, a monovalent non-aromatic condensed C8-C60 polycyclic group, and a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group; a C3-C10 cycloalkyl group, a C1-C10 heterocycloalkyl group, a C3-C10 cycloalkenyl group, a C1-C10 heterocycloalkenyl group, a C6-C60 aryl group, a C6-C60 aryloxy group, a C6-C60 arylthio group, a C1-C60 heteroaryl group, a monovalent non-aromatic condensed C8-C60 polycyclic group, and a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group; a C3-C10 cycloalkyl group, a C1-C10 heterocycloalkyl group, a C3-C10 cycloalkenyl group, a C1-C10 heterocycloalkenyl group, a C6-C60 aryl group, a C6-C60 aryloxy group, a C6-C60 arylthio group, a C1-C60 heteroaryl group, a monovalent non-aromatic condensed C8-C60 polycyclic group, and a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group; a C3-C10 cycloalkyl group, a C1-C10 heterocycloalkyl group, a C3-C10 cycloalkenyl group, a C1-C10 heterocycloalkenyl group, a C6-C60 aryl group, a C6-C60 aryloxy group, a C6-C60 arylthio group, a C1-C60 heteroaryl group, a monovalent non-aromatic condensed C8-C60 polycyclic group, and a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group; a C3-C10 cycloalkyl group, a C1-C10 heterocycloalkyl group, a C3-C10 cycloalkenyl group, a C1-C10 heterocycloalkenyl group, a C6-C60 aryl group, a C6-C60 aryloxy group, a C6-C60 arylthio group, a C1-C60 heteroaryl group, a monovalent non-aromatic condensed C8-C60 polycyclic group, and a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group; a C3-C10 cycloalkyl group, a C1-C10 heterocycloalkyl group, a C3-C10 cycloalkenyl group, a C1-C10 heterocycloalkenyl group, a C6-C60 aryl group, a C6-C60 aryloxy group, a C6-C60 arylthio group, a C1-C60 heteroaryl group, a monovalent non-aromatic condensed C8-C60 polycyclic group, and a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group; a C3-C10 cycloalkyl group, a C1-C10 heterocycloalkyl group, a C3-C10 cycloalkenyl group, a C1-C10 heterocycloalkenyl group, a C6-C60 aryl group, a C6-C60 aryloxy group, a C6-C60 arylthio group, a C1-C60 heteroaryl group, a monovalent non-aromatic condensed C8-C60 polycyclic group, and a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group; a C3-C10 cycloalkyl group, a C1-C10 heterocycloalkyl group, a C3-C10 cycloalkenyl group, a C1-C10 heterocycloalkenyl group, a C6-C60 aryl group, a C6-C60 aryloxy group, a C6-C60 arylthio group, a C1-C60 heteroaryl group, a monovalent non-aromatic condensed C8-C60 polycyclic group, and a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group; a C3-C10 cycloalkyl group, a C1-C10 heterocycloalkyl group, a C3-C10 cycloalkenyl group, a C1-C10 heterocycloalkenyl group, a C6-C60 aryl group, a C6-C60 aryloxy group, a C6-C60 arylthio group, a C1-C60 heteroaryl group, a monovalent non-aromatic condensed C8-C60 polycyclic group, and a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group.

L_{401} may be an organic ligand; xc1 may be 1, 2, or 3; and xc2 may be 0, 1, 2, or 3; Q_{401} to Q_{407}, Q_{411} to Q_{417}, and Q_{421} to Q_{427} may be each independently selected from hydrogen, a C1-C60 alkyl group, a C2-C60 alkenyl group, a C6-C60 aryl group, and a C1-C60 heteroaryl group.
dimethyl-3-pyrazolecarboxylate, and/or benzoate), a carbon monoxide ligand, an isonitrile ligand, a cyano ligand, and a phosphorous ligand (e.g., phosphine and/or phosphate), but is not limited thereto.

[0125] When A401 in Formula 401 has two or more substituents, the substituents of A401 may be linked to each other to form a saturated or unsaturated ring.

[0126] When A402 in Formula 401 has two or more substituents, the substituents of A402 may be linked to each other to form a saturated or unsaturated ring.

[0127] 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, A401 and A402 of one ligand may be each independently connected to (e.g., coupled to) A401 and A402 of other neighboring ligands, respectively, either directly (e.g., via a bond such as a single bond) or via a linker (e.g., a C1-C5 alkylene group, a C2-C5 alkenylene group, -N(R')- (wherein R' may be a C1-C10 alkyl group or a C6-C20 aryl group) and/or -C(=O)-) therebetween.

[0128] The phosphorescent dopant may comprise at least one of Compounds PD1 to PD74 below, but is not limited thereto:

PD1

PD2

PD3

PD4

PD5

PD6
In some embodiments, the phosphorescent dopant may comprise PtOEP:

The fluorescent dopant may comprise at least one selected from DPVBi, DPAVBi, TBPe, DCM, DCJTB, Coumarin 6, and C545T.
In some embodiments, the fluorescent dopant may comprise a compound represented by Formula 501 below.

\[
\text{Ar}_{501} \left[ \begin{array}{c} \text{L}_{501}^d \text{xd} 3 \text{N} \text{L}_{502}^d \\ \text{L}_{501}^d \text{xd} 2 \text{R}_{502} \end{array} \right] \text{xd} 4
\]

Descriptions of L\textsubscript{501} to L\textsubscript{503} may be the same as the description of L\textsubscript{201} provided herein; R\textsubscript{501} and R\textsubscript{503} may be each independently selected from:

- a naphthalene, a heptalene, a fluorene, a spiro-fluorene, a benzofluorene, 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
- a naphthalene, a heptalene, a fluorene, a spiro-fluorene, a benzofluorene, 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\textsubscript{6}-C\textsubscript{60} alkyl group, a C\textsubscript{2}-C\textsubscript{60} alkenyl group, a C\textsubscript{2}-C\textsubscript{60} alkynyl group, a C\textsubscript{1}-C\textsubscript{60} alkoxy group, a C\textsubscript{3}-C\textsubscript{10} cycloalkyl group, a C\textsubscript{1}-C\textsubscript{10} cycloalkenyl group, a C\textsubscript{1}-C\textsubscript{10} heterocycloalkyl group, a C\textsubscript{1}-C\textsubscript{10} heterocycloalkenyl group, a C\textsubscript{6}-C\textsubscript{60} aryloxy group, a C\textsubscript{6}-C\textsubscript{60} aryl group, a C\textsubscript{6}-C\textsubscript{60} arylthio group, a C\textsubscript{1}-C\textsubscript{60} heteroaryl group, a monovalent non-aromatic condensed C\textsubscript{8}-C\textsubscript{60} polycyclic group, a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group.

Each L\textsubscript{501} to L\textsubscript{503} may be each independently selected from a naphthalene, a heptalene, a fluorene, a spiro-fluorene, a benzofluorene, 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, a naphthalene, a heptalene, a fluorene, a spiro-fluorene, a benzofluorene, 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\textsubscript{6}-C\textsubscript{60} alkyl group, a C\textsubscript{2}-C\textsubscript{60} alkenyl group, a C\textsubscript{2}-C\textsubscript{60} alkynyl group, a C\textsubscript{1}-C\textsubscript{60} alkoxy group, a C\textsubscript{3}-C\textsubscript{10} cycloalkyl group, a C\textsubscript{1}-C\textsubscript{10} cycloalkenyl group, a C\textsubscript{1}-C\textsubscript{10} heterocycloalkyl group, a C\textsubscript{1}-C\textsubscript{10} heterocycloalkenyl group, a C\textsubscript{6}-C\textsubscript{60} aryloxy group, a C\textsubscript{6}-C\textsubscript{60} aryl group, a C\textsubscript{6}-C\textsubscript{60} arylthio group, a C\textsubcript{1}-C\textsubscript{60} heteroaryl group, a monovalent non-aromatic condensed C\textsubscript{8}-C\textsubscript{60} polycyclic group, a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic 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 pyrazidinyl group, a quinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyrazidinyl group, a quinolinyl 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 C1-C20 alkyl group, a C1-C20 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 isoquinoliny group, a quinoxaliny group, a quinazolinyl group, a carbazolyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

dx1 to xd3 may be each independently selected from 0, 1, 2, and 3; and

[0133] For example, the fluorescent dopant may comprise at least one of Compounds FD1 to FD8:

FD1

FD2

FD3

FD4

FD5

FD6
An amount of the dopant in the emission layer may be in a range of about 0.01 to about 15 parts by weight based on 100 parts by weight of the host, but is not limited thereto.

A thickness of the emission layer may be in a range of about 100 Å to about 1,000 Å, for example, about 200 Å to about 600 Å. When the thickness of the emission layer is within any of these ranges, excellent (or suitable) light-emission characteristics may be obtained without a substantial increase in driving voltage.

An electron transport region may be disposed (e.g., positioned) on the emission layer.

The electron transport region may comprise at least one selected from a hole blocking layer, an electron transport layer, and an electron injection layer, but is not limited thereto.

For example, the electron transport region may have a structure of electron transport layer/electron injection layer or a structure of hole blocking layer/electron transport layer/electron injection layer, wherein the layers of each structure are sequentially stacked in a direction from the emission layer in the stated order, but the structure of the electron transport region is not limited thereto.

In some embodiments, the electron transport region may comprise a hole blocking layer. When the emission layer comprises a phosphorescent dopant, the hole blocking layer may be formed to prevent or reduce the diffusion of excitons or holes into an electron transport layer.

When the electron transport region comprises a hole blocking layer, the hole blocking layer may be formed on the emission layer by using one or more methods selected from vacuum deposition, spin coating, casting, an 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, 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.

The hole blocking layer may comprise, for example, at least one selected from BCP and Bphen, but is not limited thereto.

A thickness of the hole blocking layer may be in a range of about 20 Å to about 1,000 Å, for example, about 30 Å to about 300 Å. When the thickness of the hole blocking layer is within any of these ranges, the hole blocking layer may have excellent (or suitable) hole blocking characteristics without a substantial increase in driving voltage.

The electron transport region may comprise an electron transport layer. The electron transport layer may be formed on the emission layer or the hole blocking layer by using one or more methods selected from vacuum deposition, spin coating, casting, an LB method, ink-jet printing, laser-printing, and laser-induced thermal imaging. When an electron transport layer is formed by vacuum deposition and/or spin coating, deposition and coating conditions for the electron transport layer may be the same as or similar to the deposition and coating conditions for the hole injection layer.

The electron transport layer may further comprise at least one selected from BCP, Bphen, Alq₃, Balq, TAZ, and NTAZ.
In some embodiments, the electron transport layer may further comprise at least one of compounds represented by Formula 601 below:

**Formula 601**

$$\text{Ar}_{601} \cdot [(\text{L}_{601})_{x1} \cdot \text{E}_{601}]_{x2}.$$  

In Formula 601, $\text{Ar}_{601}$ is as defined herein for $\text{Ar}_{301}$; $\text{L}_{601}$ is as defined herein for $\text{L}_{201}$; $\text{E}_{601}$ may be selected from:

- 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, a quinoxalinyl group, a carbazolyl group, a phenanthrylidnyl group, an acridinyl group, a phenanthrolinyl group, a benzoimidazolyl 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 dibenzocarbazolyl 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, a quinoxalinyl group, a carbazolyl group, a phenanthrylidnyl group, an acridinyl group, a phenanthrolinyl group, a benzoimidazolyl 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 dibenzocarbazolyl group;
naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phthalazine group, a benzoimidazolyl group, a benzothiazolyl group, an isobenzofuranyl group, an acridinyl group, a phenanthrolinyl group, a triazinyl group, a dibenzo[f]thiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group;

xe₁ may be selected from 0, 1, 2, and 3; and
xe₂ may be selected from 1, 2, 3, and 4.

[0147] In some embodiments, the electron transport layer may further comprise at least one of compounds represented by Formula 602 below:

**Formula 602**

![Formula 602 diagram](image)

[0148] In Formula 602, X₆₁₁ may be N or C-(L₆₁₁)xe₆₁₁-R₆₁₁, X₆₁₂ may be N or C-(L₆₁₂)xe₆₁₂-R₆₁₂, X₆₁₃ may be N or C-(L₆₁₃)xe₆₁₃-R₆₁₃, and at least one selected from X₆₁₁ to X₆₁₃ may be N;

L₆₁₁ to L₆₁₆ are each independently as defined herein for L₂₀₁;

R₆₁₁ to R₆₁₆ may be each independently selected from:

a phenyl group, a naphthyl group, a fluorenyl group, a benzofluorenyle group, a dibenzofluorenyle group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridyl group, a pyrazinyl group, a pyrazinc group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a carbazolyl group, and a triazinyl group; and

a phenyl group, a naphthyl group, a fluorenyl group, a benzofluorenyle group, a dibenzofluorenyle group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridyl group, a pyrazinyl group, a pyrazinc group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl 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, an amino group, a hydrazine group, a hydrazine group, a cyano group, a nitro group, an amino group, an amidino group, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C₁-C₂₀, alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a naphthyl group, an azulenyl group, a fluorenyl group, a benzofluorenyle group, a dibenzofluorenyle group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridyl group, a pyrazinyl group, a pyrazinc group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, and a triazinyl group; and

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

[0149] The compound represented by Formula 601 and the compound represented by Formula 602 may each independently comprise at least one of Compounds ET₁ to ET₁₆ illustrated below.
A thickness of the electron transport layer may be in a range of about 100 Å to about 1,000 Å, for example, about 150 Å to about 500 Å. When the thickness of the electron transport layer is within any of the ranges described above, the electron transport layer may have satisfactory (or suitable) electron transport characteristics without a substantial increase in driving voltage.

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

The metal-containing material may comprise a Li complex. The Li complex may comprise, for example, Compound ET-D1 (lithium quinolate, LiQ) and/or Compound ET-D2.
The electron transport region may comprise an electron injection layer that facilitates the injection of electrons from the second electrode 190.

The electron injection layer may be formed on the electron transport layer by using one or more methods selected from vacuum deposition, spin coating, casting, an 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, deposition and coating conditions for the electron injection layer may be the same as or similar to those for the hole injection layer.

The electron injection layer may comprise at least one selected from LiF, NaCl, CsF, Li$_2$O, BaO, and LiQ.

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

The second electrode 190 may be disposed (e.g., positioned) on the organic layer 150 having the structure according to embodiments of the present disclosure. The second electrode 190 may be a cathode, which is an electron injection electrode, and in this regard, a material for forming the second electrode 190 may be selected from a metal, an alloy, an electrically conductive compound, and a mixture thereof, which have a relatively low work function. Non-limiting examples of the second electrode 190 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.

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

FIG. 2 is a schematic cross-sectional view of an organic light-emitting device 20 according to an embodiment of the present disclosure.

Referring to FIG. 2, the organic light-emitting device 20 comprises a substrate 210 that is divided according to a first sub-pixel region, a second sub-pixel region, and a third sub-pixel region.

A first sub-pixel is formed in the first sub-pixel region, a second sub-pixel is formed in the second sub-pixel region, and a third sub-pixel is formed in the third sub-pixel region.

A plurality of first electrodes 221, 222, and 223 are disposed (e.g., positioned) in the first sub-pixel region, the second sub-pixel region, and the third sub-pixel region, respectively. That is, the first electrode 221 is disposed in the first sub-pixel region, the first electrode 222 is disposed in the second sub-pixel region, and the first electrode 223 is disposed in the third sub-pixel region.

A hole transport region 240 is disposed on the first electrodes 221, 222, and 223. The hole transport region 240 may be formed as a common layer on the first electrodes 221, 222, and 223. The hole transport region 240 may comprise a first hole transport region formed in the first sub-pixel region; a second hole transport region formed in the second sub-pixel region; and a third hole transport region formed in the third sub-pixel region. For example, the hole transport region 240 may comprise the first compound represented by Formula 1 and the second compound represented by Formula 2.

In some embodiments, the hole transport region 240 comprises a first layer and a second layer, where the second layer is disposed between the first layer and the first electrodes 221, 222 and 223. The first layer may comprise the first compound represented by Formula 1, and the second layer may comprise the second compound represented by Formula 2, but the structure of the hole transport region 240 is not limited thereto.

The first compound represented by Formula 1 and the second compound represented by Formula 2 are as described above.

An emission layer comprising a first emission layer 261, a second emission layer 262, and a third emission...
layer 263 may be formed on the hole transport region 240. The first emission layer 261 is formed in the first sub-pixel region and emits first color light (e.g., light of a first color), the second emission layer 262 is formed in the second sub-pixel region and emits second color light (e.g., light of a second color), and the third emission layer 263 is formed in the third sub-pixel region and emits third color light (e.g., light of a third color). For example, at least one of the first emission layer 261, the second emission layer 262, and the third emission layer 263 may comprise the compound represented by Formula 1.

[0167] For example, the first color light may be red light, the second color light may be green light, and the third color light may be blue light. The first color light, the second color light, and the third color light may be combined with each other to form white light.

[0168] An electron transport region 270 may be formed on the first, second, and third emission layers 261, 262, and 263. The electron transport region 270 may be formed as a common layer on the first, second, and third emission layers 261, 262, and 263. The electron transport region 270 may comprise an electron transport layer and an electron injection layer, which are sequentially stacked on the first, second, and third emission layers 261, 262, and 263 in this stated order.

[0169] A second electrode 280 may be formed as a common layer on the electron transport region 270.

[0170] The expression “common layer” used herein may refer to a layer that is commonly formed in the first sub-pixel region, the second sub-pixel region, the third sub-pixel region, without being patterned according to the first sub-pixel region, the second sub-pixel region, and the third sub-pixel region.

[0171] A pixel insulating film 230 may be formed on the edges of each of the first electrodes 221, 222, and 223. The pixel insulating film 230 may define a pixel region, and may comprise any suitable organic insulating material, inorganic insulating material (such as a silicon-based material), and/or an organic/inorganic composite insulating material.

[0172] The first electrodes 221, 222, and 223, the hole transport region 240, the first, second, and third emission layers 261, 262, and 263, the electron transport region 270 and the second electrode 280 are as described herein for the first electrode, hole transport region, emission layer, electron transport region, and second electrode in connection with FIG. 1.

[0173] The organic light-emitting device 20 may be used in a flat panel display device comprising a thin film transistor. The thin film transistor may comprise a gate electrode, source and drain electrodes, a gate insulating film, and an active layer, and one of the source electrode and drain electrode may electrically contact (e.g., may be electrically coupled to) the first electrodes 221, 222, and 223 of the organic light-emitting device 20. The active layer may comprise crystalline silicon, amorphous silicon, organic semiconductor, oxide semiconductor, and/or the like, but embodiments of the present disclosure are not limited thereto.

[0174] Hereinafter, a full-color organic light-emitting device 20 has been described with reference to FIG. 2, but embodiments of the present disclosure are not limited thereto. For example, the third emission layer 263 may extend to the first sub-pixel region and the second sub-pixel region, thereby forming a common emission layer.

[0175] A C1-C60 alkyl group used herein may refer to a linear or branched aliphatic hydrocarbon monovalent group having 1 to 60 carbon atoms, e.g., 1 to 30 carbon atoms, 1 to 20 carbon atoms, 1 to 10 carbon atoms, 1 to 6 carbon atoms or 1 to 4 carbon atoms. Non-limiting examples thereof are a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, a pentyl group, an iso-amyl group, and a hexyl group. A C1-C60 alkoxy group used herein may refer to a divalent group having the same structure as the C1-C60 alkyl group.

[0176] A C1-C60 alkoxy group used herein may refer to a monovalent group represented by -OA101 (wherein A101 is the C1-C60 alkyl group), and non-limiting examples thereof are a methoxy group, an ethoxy group, and an isopropanoxy group.

[0177] A C2-C60 alkenyl group used herein may refer to a hydrocarbon group having at least one carbon double bond at one or more positions along the hydrocarbon chain of the C2-C60 alkyl group (e.g., in the middle or at either terminal end of the C2-C60 alkyl group), and non-limiting examples thereof are an ethenyl group, a propenyl group, and a butenyl group. A C2-C60 alkenyl group used herein may refer to a divalent group having the same structure as the C2-C60 alkenyl group.

[0178] A C2-C60 alkenyl group used herein may refer to a hydrocarbon group having at least one carbon triple bond at one or more positions along the hydrocarbon chain of the C2-C60 alkyl group (e.g., in the middle or at either terminal end of the C2-C60 alkyl group), and non-limiting examples thereof are an ethinyl group and a propinyl group. A C2-C60 alkenyl group used herein may refer to a divalent group having the same structure as the C2-C60 alkyl group.

[0179] A C3-C10 cycloalkyl group used herein may refer to a monovalent hydrocarbon monocyclic group having 3 to 10 carbon atoms, and non-limiting examples thereof are a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. A C3-C10 cycloalkyl group used herein may refer to a divalent group having the same structure as the C3-C10 cycloalkyl group.

[0180] A C1-C10 heterocycloalkyl group used herein may refer to a monovalent monocyclic group having at least one heteroatom (e.g., 1, 2, 3, 4 or 5 heteroatoms) selected from N, O, P, and S as a ring-forming atom, and 1 to 10 carbon atoms, e.g., 1, 2, 3, 4 or 5 ring carbon atoms. Non-limiting examples thereof are a tetrahydrofuranyl group and a tetrahydrothiophenyl group. A C1-C10 heterocycloalkyl group used herein may refer to a divalent group having the same
structure as the C$_{1}$-C$_{10}$ heterocycloalkyl group.

**[0181]** A C$_{3}$-C$_{10}$ cycloalkenyl group used herein may refer to a monovalent monocyclic group that has 3 to 10 carbon atoms and at least one double bond in the ring thereof, and does not have aromaticity, and non-limiting examples thereof are a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. A C$_{3}$-C$_{10}$ cycloalkenylene group used herein may refer to a divalent group having the same structure as the C$_{3}$-C$_{10}$ cycloalkenyl group.

**[0182]** A C$_{1}$-C$_{10}$ heterocycloalkenyl group used herein may refer to a monovalent monocyclic group that has at least one heteroatom (e.g. 1, 2, 3, 4 or 5 heteroatoms) selected from N, O, P, and S as a ring-forming atom, 1 to 10 carbon atoms, e.g. 1, 2, 3, 4 or 5 ring carbon atoms, and at least one double bond in its ring. Non-limiting examples of the C$_{1}$-C$_{10}$ heterocycloalkenyl group are a 2,3-dihydrofuranyl group and a 2,3-dihydrothiophenyl group. A C$_{1}$-C$_{10}$ heterocycloalkenylene group used herein may refer to a divalent group having the same structure as the C$_{1}$-C$_{10}$ heterocycloalkenyl group.

**[0183]** A C$_{6}$-C$_{60}$ aryl group used herein may refer to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms e.g. 6 to 20 ring carbon atoms, 6 to 14 ring carbon atoms or 6 to 10 ring carbon atoms. A C$_{6}$-C$_{60}$ arylene group used herein may refer 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 are a phenyl 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 independently comprise two or more rings, the respective rings may be fused to each other.

**[0184]** A C$_{1}$-C$_{60}$ heteroaryl group used herein may refer to a monovalent group having a carbocyclic aromatic system that has at least one heteroatom (e.g. 1, 2, 3, 4 or 5 heteroatoms) selected from N, O, P, and S as a ring-forming atom, and 1 to 60 carbon atoms, e.g. 1 to 19 ring carbon atoms, 1 to 13 ring carbon atoms or 1 to 9 ring carbon atoms. A C$_{1}$-C$_{60}$ heteroaryl group may refer to the divalent group having a carbocyclic aromatic system that has at least one heteroatom (e.g. 1, 2, 3, 4 or 5 heteroatoms) selected from N, O, P, and S as a ring-forming atom, and 1 to 60 carbon atoms, e.g. 1 to 19 ring carbon atoms, 1 to 13 ring carbon atoms or 1 to 9 ring carbon atoms. Non-limiting examples of the C$_{1}$-C$_{60}$ heteroaryl group are a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, an isoquinolinyl group, and a quinolinyl group. When the C$_{1}$-C$_{60}$ heteroaryl group and the C$_{6}$-C$_{60}$ aryl group each independently comprise two or more rings, the respective rings may be fused to each other.

**[0185]** A C$_{5}$-C$_{60}$ aryloxy group used herein may refer to a monovalent group represented by -OA$_{102}$ (wherein A$_{102}$ is the C$_{5}$-C$_{60}$ aryl group), and a C$_{6}$-C$_{60}$ arylthio group may refer to a monovalent group represented by -SA$_{103}$ (wherein A$_{103}$ is the C$_{6}$-C$_{60}$ aryl group).

**[0186]** A non-limiting example of the monovalent non-aromatic condensed C$_{5}$-C$_{60}$ polycyclic group used herein may refer to a monovalent group that has two or more rings condensed to each other, only carbon atoms (for example, the number of carbon atoms may be in a range of 8 to 60, 8 to 20, 8 to 14 or 8 to 10) as ring-forming atoms, and does not have overall aromaticity in the entire molecular structure. A non-limiting example of the monovalent non-aromatic condensed C$_{6}$-C$_{60}$ polycyclic group is a fluorenlyl group. A divalent non-aromatic condensed C$_{5}$-C$_{60}$ polycyclic group used herein may refer to a divalent group having the same structure as the monovalent non-aromatic condensed C$_{5}$-C$_{60}$ polycyclic group.

**[0187]** A non-limiting example of the monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group used herein may refer to a monovalent group that has two or more rings condensed to each other, has at least one heteroatom (e.g. 1, 2, 3, 4, or 5 heteroatoms) selected from N, O, P, and S, and carbon atoms (for example, the number of carbon atoms may be in a range of 2 to 59, 2 to 19, 2 to 13 or 2 to 9), as ring-forming atoms, and does not have overall aromaticity in the entire molecular structure. A non-limiting example of the monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group is a carbazolyl group. A divalent non-aromatic condensed 8- to 60-membered heteropolycyclic group used herein may refer to a divalent group having the same structure as the monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group.

**[0188]** A C$_{5}$-C$_{20}$ cyclic group as used herein is a cycloalkyl group, a cycloalkenyl group, an aryl group or a monovalent non-aromatic condensed C$_{5}$-C$_{60}$ polycyclic group, as described above, having 5 to 20 ring forming carbon atoms. A C$_{5}$-C$_{20}$ cyclic group is typically an aryl group.

**[0189]** A C$_{1}$-C$_{20}$ heterocyclic group as used herein is a heterocycloalkyl group, a heterocycloalkenyl group, a heteroaryl group or a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group, as described above, having 1 to 20 ring-forming carbon atoms. A C$_{1}$-C$_{20}$ heterocyclic group is typically a heteroaryl group.

**[0190]** Certain groups are specified herein as being substituted or unsubstituted. Unless otherwise specified, when a group is substituted it is typically substituted with 1, 2, 3 or 4 substituents. For example, when a group is substituted it may substituted with 1, 2 or 3 substituents; 1 or 2 substituents; or 1 substituent. Groups which are not specified as being substituted or unsubstituted are typically unsubstituted.

**[0191]** Unless otherwise specified, when a group is substituted it is typically substituted with at least one substituent (e.g. 1, 2, 3 or 4 substituents) 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 hydrazon 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
For example, unless otherwise specified, when a group is substituted it may be substituted with at least one substituent selected from:

- A C1-C10 heterocycloalkyl group,
- A C3-C10 cycloalkenyl group,
- A C1-C10 heterocycloalkenyl group,
- A C6-C60 aryl group,
- A C6-C60 arilox group,
- A C6-C60 arilthio group,
- A C1-C60 heteroaryl group,
- An amidino group,
- A hydrazine group,
- A hydrazone group,
- A carboxylic acid group or a salt thereof,
- A phosphoric acid group or a salt thereof,
- A C3-C10 cycloalkyl group,
- A C1-C10 heteroalkyl group,
- A monovalent non-aromatic condensed C6-C60 polycyclic group,
- A monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group, -N(Q11)(Q12),
- -Si(Q13)(Q14)(Q15), and -B(Q16)(Q17);

wherein Q11 to Q17, Q21 to Q27, and Q31 to Q37 may be each independently selected from hydrogen, a C1-C60 alkyl group, a C2-C60 alkenyl group, a C2-C60 alkynyl group, a C1-C60 alkoxy group, a C1-C60 alkyl group, a C2-C60 alkenyl group, a C2-C60 alkynyl group, a C1-C60 alkoxy group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C1-C60 alkyl group, a C2-C60 alkenyl group, a C2-C60 alkynyl group, a C1-C60 alkoxy group, a C2-C60 alkenyl group, a C2-C60 alkynyl group, a C1-C60 alkoxy group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C1-C60 alkyl group, a C2-C60 alkenyl group, a C2-C60 alkynyl group, a C1-C60 alkoxy group, a C2-C60 alkenyl group, a C2-C60 alkynyl group, a C1-C60 alkoxy group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C3-C10 cycloalkyl group, a C6-C60 aryloxy group, a C6-C60 arythio group, a C1-C60 heteroary group, a monovalent non-aromatic condensed C6-C60 polycyclic group, and a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group.

[0192] For example, unless otherwise specified, when a group is substituted it may be substituted with at least one substituent selected from:

deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C1-C30 alkly group, a C2-C30 alkenyl group, a C2-C30 alkynyl group, and a C1-C30 alkoxy group; a C3-C6 alkyl group, a C2-C30 alkenyl group, a C2-C30 alkynyl group, and a C1-C30 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 C1-C30 alkyl group, a C2-C30 alkenyl group, a C2-C30 alkynyl group, a C1-C30 alkoxy group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C3-C10 cycloalkyl group, a C6-C60 aryloxy group, a C6-C60 arythio group, a C1-C60 heteroary group, a monovalent non-aromatic condensed C6-C60 polycyclic group, a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group, -N(Q11)(Q12), -Si(Q13)(Q14)(Q15), and -B(Q16)(Q17); and

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

wherein Q11 to Q17, Q21 to Q27, and Q31 to Q37 may be each independently selected from hydrogen, a C1-C60 alkyl group, a C2-C60 alkenyl group, a C2-C60 alkynyl group, a C1-C60 alkoxy group, a C2-C60 alkenyl group, a C2-C60 alkynyl group, a C1-C60 alkoxy group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C1-C60 alkyl group, a C2-C60 alkenyl group, a C2-C60 alkynyl group, a C1-C60 alkoxy group, a C2-C60 alkenyl group, a C2-C60 alkynyl group, a C1-C60 alkoxy group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C3-C10 cycloalkyl group, a C6-C60 aryloxy group, a C6-C60 arythio group, a C1-C60 heteroary group, a monovalent non-aromatic condensed C6-C60 polycyclic group, and a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group.

- N(Q11)(Q12), -Si(Q13)(Q14)(Q15), and -B(Q16)(Q17);

- a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysene group, a naphtacenule group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pyrrolyl group, an imidazolyl group, a pyrazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazine group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoxazinyl group, a benzoazoxinyl group, a benzimidazoxinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthroline group, a phenaizinyl group, a benzoxazolyl group, a benzoazoxolyl group, a furanyl group, a benzofuranyl group, a thiophenyl group, a benzothiophenyl group, a thiazolyl group, an isothiazolyl
group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofurananyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group;

a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysensyl group, a napthacenyenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pyrrolyl group, a pyrazinyl group, a phenazinyl group, a benzoquinolinyl group, a benzoimidazolyl group, a pyridinyl group, a pyridyl group, a benzopyridinyl group, a benzoquinolinyl group, a benzoimidazolyl group, a pyridinyl group, a pyridyl group, a naphthyridinyl group, a quinazolyl group, a quinoxalinyl group, a pyridazinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoquinolinyl group, a benzoimidazolyl group, a furanyl group, a benzofurananyl group, a thiophenyl group, a benzothiophenyl group, a triazolyl group, an isothiazolyl group, a benzothiazolyl group, an isoxazolyl group, an oxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofurananyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group;

a C1-C30 alkyl group, a C2-C30 alkenyl group, a C2-C30 alkynyl group, a C1-C30 alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, a cyclopentenyl group, a cycloheptenyl group, a phenyl group, a biphenyl group, a dibenzocarbazolyl group, a dibenzo- carbazolyl group, a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a pyridinyl group, an indolyl group, an indolyl group, an indolyl group, an indolyl group, an indolyl group, a pyridyl group, a pyridyl group, a pyridyl group, a pyridyl group, a pyridyl group, a pyridyl group, a pyridyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoxazolyl group, a benzoimidazolyl group, a furanyl group, a benzofurananyl group, a thiophenyl group, a benzothiophenyl group, a triazolyl group, an isothiazolyl 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 phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysensyl group, a napthacenyenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pyrrolyl group, a pyrazinyl group, a phenazinyl group, an imidazopyrimidinyl group, and an imidazopyridinyl group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, a hydroxy group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazine group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C1-C30 alkyl group, a C2-C30 alkenyl group, a C2-C30 alkynyl group and C1-C30 alkoxy group, a C3-C10 cycloalkenyl group, a C1-C10 heterocycloalkenyl group, a C3-C30 aryl group, a C6-C30 aryl group, a C6-C30 arylthio group, a C7-C30 heteroaryl group, a monovalent non-aromatic condensed C6-C60 polycyclic group, a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group, -N(Q21)(Q22), -Si(Q23)(Q24)(Q25), and -B(Q26)(Q27); and

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

wherein Q11 to Q17, Q21 to Q27, and Q31 to Q37 may be each independently selected from a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysensyl group, a napthacenyenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pyrrolyl group, an imidazopyrimidinyl group, a pyrazinyl group, a pyridinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indolyl group, an indolyl group, an indolyl group, a pyridyl group, a pyridyl group, a pyridyl group, a pyridyl group, a pyridyl group, a pyridyl group, a pyridyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoxazolyl group, a benzoimidazolyl group, a furanyl group, a benzofurananyl group, a thiophenyl group, a benzothiophenyl group, a triazolyl group, an isothiazolyl 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 phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysensyl group, a napthacenyenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pyrrolyl group, an imidazopyrimidinyl group, a pyrazinyl group, a pyridinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indolyl group, an indolyl group, an indolyl group, a pyridyl group, a pyridyl group, a pyridyl group, a pyridyl group, a pyridyl group, a pyridyl group, a pyridyl group, a quinolinyl group, an isoquinolinyl group, a phthalazinyl group, a quinoxalinyl group, a cinnolinyl group, and a quinazolinyl group, but are not limited thereto.

[0193] The term "Ph" used herein may refer to a phenyl group, the term "Me" used herein may refer to a methyl group, the term "Et" used herein may refer to an ethyl group, and the term "ter-Bu" or "Bu" used herein may refer to a tert-butyl group.

[0194] Hereinafter, an organic light-emitting device according to one or more embodiments of the present disclosure is described in more detail with reference to Synthesis Example and Examples. However, the organic light-emitting device of the present embodiments is not limited thereto.

[0195] The expression "B was used instead of A" used in describing Synthesis Examples may refer to a molar equivalent of A being identical to a molar equivalent of B. As used herein, the term "eq" may refer to a molar equivalent.
Examples

Synthesis Examples: Synthesis of Intermediates

1) Synthesis of Int-1

\[0196\]

\[
Pd(dba)_3 (0.03\text{eq}), (t\text{-Bu})_3P (0.06\text{eq}), \text{and toluene (0.1M based on i-iodo-2-nitrobenzene)} \text{were added to a flask containing 3-bromo-9H-carbazole (0.8eq) and 1-iodo-2-nitrobenzene (1eq), and the resulting mixture was reflux-stirred for 12 hours. Once the reaction was complete, the mixture was cooled to room temperature, and then, subjected to an extraction process using methylene chloride, and then, the extraction result was washed with distilled water. A collected organic layer was dried by using MgSO}_4 \text{and distilled under reduced pressure. The obtained residual was purified by column chromatography to obtain Int-1 (yield of 68%). Int-1 was identified by High Resolution Mass Spectrometry (HRMS).} \]

\[0198\]

\[
C_{18}H_{11}BrN_2O_2 [M]^+: \text{calculated: 367.20, found: 366}
\]

2) Synthesis of Int-2 and Int-3

\[0199\]

\[
\text{Int-1 (1eq) was dissolved in triethylphosphite (10eq), and then, reflux-stirred under nitrogen stream for 12 hours. Once the reaction was complete, the remaining triethylphosphite was removed therefrom by vacuum distillation. Then, the result was purified by column chromatography (using hexane:methylene chloride = 4:1 (v/v) as solvent to obtain}
\]

[0200]
Int-2 (yield of 46.5%) and Int-3 (yield of 41.6%). Int-2 and Int-3 were each identified by HRMS.

**3) Synthesis of Int-4**

Pd(dba)$_3$ (0.03eq), (t-Bu)$_3$P (0.06eq), and toluene (0.1M based on iodobenzene) were added to a flask containing Int-2 (0.8eq) and iodobenzene (1eq), and then, the resulting mixture was reflux-stirred for 3 hours. Once the reaction was complete, the mixture was cooled to room temperature and subjected to an extraction process using methylene chloride, and the extraction result was washed with distilled water. A collected organic layer was dried by using MgSO$_4$ and distilled under reduced pressure to obtain the residual, which was then purified by column chromatography to obtain Int-4 (yield of 82%). Int-4 was identified by HRMS.

**4) Synthesis of Int-5**

Pd(dba)$_3$ (0.03eq), (t-Bu)$_3$P (0.06eq), and toluene (0.1M based on iodobenzene) were added to a flask containing Int-3 (0.8eq) and iodobenzene (1eq), and then, the resulting mixture was reflux-stirred for 3 hours. Once the reaction was complete, the mixture was cooled to room temperature and subjected to an extraction process using methylene chloride, and the extraction result was washed with distilled water. A collected organic layer was dried by using MgSO$_4$ and distilled under reduced pressure to obtain the residual, which was then purified by column chromatography to obtain Int-5 (yield of 82%). Int-5 was identified by HRMS.
5) Synthesis of Int-6

Pd(dba)$_3$ (0.03eq), (t-Bu)$_3$P (0.06eq), and toluene (0.1M based on 4-iodobenzo[b,d]thiophene) were added to a flask containing Int-2 (0.8eq) and 4-iodobenzo[b,d]thiophene (1eq), and then, the resulting mixture was reflux-stirred for 3 hours. Once the reaction was complete, the mixture was cooled to room temperature and subjected to an extraction process using methylene chloride, and the extraction result was washed with distilled water. A collected organic layer was dried by using MgSO$_4$ and distilled under reduced pressure to obtain the residual, which was then purified by column chromatography to obtain Int-6 (yield of 76%). Int-6 was identified by HRMS.

C$_{30}$H$_{17}$BrN$_2$S$[M]+$: calculated: 517.44, found: 516

6) Synthesis of Int-7

Pd(dba)$_3$ (0.03eq), (t-Bu)$_3$P (0.06eq), and toluene (0.1M based on 9,9-dimethyl-9H-fluorene-2-amine) were added to a flask containing 9,9-dimethyl-9H-fluorene-2-amine (1eq) and 3-bromo-9-phenyl-9H-carbazole (0.9eq), and then, the resulting mixture was reflux-stirred for 3 hours. Once the reaction was complete, the mixture was cooled to room temperature and subjected to an extraction process using methylene chloride, and the extraction result was washed with distilled water. A collected organic layer was dried by using MgSO$_4$ and distilled under reduced pressure to obtain the residual, which was then purified by column chromatography to obtain Int-7 (yield of 69%). Int-7 was identified by HRMS.

HRMS (C$_{33}$H$_{26}$N$_2$ [M]+): calculated; 450.59, found; 449

7) Synthesis of Int-8

Pd(dba)$_3$ (0.03eq), (t-Bu)$_3$P (0.06eq), and toluene (0.1M based on 9,9-dimethyl-9H-fluorene-2-amine) were added to a flask containing 9,9-dimethyl-9H-fluorene-2-amine (1eq) and 3-bromo-9-phenyl-9H-carbazole (0.9eq), and then, the resulting mixture was reflux-stirred for 3 hours. Once the reaction was complete, the mixture was cooled to room temperature and subjected to an extraction process using methylene chloride, and the extraction result was washed with distilled water. A collected organic layer was dried by using MgSO$_4$ and distilled under reduced pressure to obtain the residual, which was then purified by column chromatography to obtain Int-7 (yield of 69%). Int-7 was identified by HRMS.

HRMS (C$_{33}$H$_{26}$N$_2$ [M]+): calculated; 450.59, found; 449
Pd(dba)$_3$ (0.03eq), (t-Bu)$_3$P (0.06eq), and toluene (0.1M based on 9,9-diphenyl-9H-fluorene-2-amine) were added to a flask containing 9,9-diphenyl-9H-fluorene-2-amine (1eq) and 4-bromo-1,1'-biphenyl (0.9eq), and then, the resulting mixture was reflux-stirred for 3 hours. Once the reaction was complete, the mixture was cooled to room temperature and subjected to an extraction process using methylene chloride, and the extraction result was washed with distilled water. A collected organic layer was dried by using MgSO$_4$ and distilled under reduced pressure to obtain the residual, which was then purified by column chromatography to obtain Int-8 (yield of 71%).

HRMS (C$_{37}$H$_{27}$N $[M]^+$): calculated: 485.63, found: 484

Synthesis Example 1: Synthesis of Compound A1

Int-5 (1eq), (3-(dibenzo[b,d]thiophene-4-yl)phenyl)boronic acid (1.2eq), Pd(PPh$_3$)$_4$ (0.02eq), Na$_2$CO$_3$ (1.2eq), and a mixture of toluene, distilled water, and ethanol (5:3:2(v/v), 0.1M based on Int-5) were loaded into a flask, and then, reflux-stirred for 12 hours. Once the reaction was complete, the mixture was cooled to room temperature and subjected to an extraction process using methylene chloride, and the extraction result was washed with distilled water. A collected organic layer was dried by using MgSO$_4$ and distilled under reduced pressure to obtain the residual, which was then purified by column chromatography to obtain Compound A1 (yield of 74%). Compound A1 was identified by Elemental analysis and HRMS.

Elemental analysis (C$_{42}$H$_{26}$N$_2$S): C(85.39), H (4.44), N (4.74), S (5.43),
HRMS (C$_{42}$H$_{26}$N$_2$S $[M]^+$): calculated: 590.74, found: 589

Synthesis Example 2: Synthesis of Compound A$_{14}$

Compound A$_{14}$ (yield of 83%) was prepared in the same (or substantially the same) manner as in Synthesis Example 1, except that Int-4 was used instead of Int-5, and (9-phenyl-9H-carbazole-3-yl)boronic acid was used instead of (3-(dibenzo[b,d]thiophene-4-yl)phenyl)boronic acid. Compound A$_{14}$ was confirmed by Elemental analysis and HRMS.

Elemental analysis (C$_{42}$H$_{27}$N$_3$): C(87.93), H (4.74), N (7.32),
HRMS (C$_{42}$H$_{27}$N$_3$ $[M]^+$): calculated: 573.70, found: 572

Synthesis Example 3: Synthesis of Compound A$_{17}$

Compound A$_{17}$ (yield of 84%) was prepared in the same (or substantially the same) manner as in Synthesis Example 1, except that Int-6 was used instead of Int-5, and dibenzo[b,d]thiophene-2-ylboronic acid was used instead of (3-(dibenzo[b,d]thiophene-4-yl)phenyl)boronic acid. Compound A$_{17}$ was identified by Elemental analysis and HRMS.

Elemental analysis (C$_{42}$H$_{24}$N$_2$S$_2$): C(81.26), H (3.90), N(4.51), S(10.33),
HRMS (C$_{42}$H$_{24}$N$_2$S$_2$ $[M]^+$): calculated: 620.79, found: 619

Synthesis Example 4: Synthesis of Compound A$_{22}$

Compound A$_{22}$ (yield of 79.2%) was prepared in the same (or substantially the same) manner as in Synthesis Example 1, except that Int-4 was used instead of Int-5, and dibenzo[b,d]furan-4-ylboronic acid was used instead of (3-(dibenzo[b,d]thiophene-4-yl)phenyl)boronic acid. Compound A$_{22}$ was identified by Elemental analysis and HRMS.

Elemental analysis (C$_{36}$H$_{22}$N$_2$O): C(86.72), H (4.45), N (5.62), O(3.21),
HRMS (C$_{36}$H$_{22}$N$_2$O $[M]^+$): calculated: 498.59, found: 497
Synthesis Example 5: Synthesis of Compound A23

Compound A23 (yield of 79.2%) was prepared in the same (or substantially the same) manner as in Synthesis Example 1, except that Int-6 was used instead of Int-5, and dibenzo[b,d]thiophene-4-ylboronic acid was used instead of (3-(dibenzo[b,d]thiophene-4-yl)phenyl)boronic acid. Compound A23 was identified by Elemental analysis and HRMS.

Elemental analysis (C_{42}H_{24}N_{2}S_{2}): C(81.26), H (3.90), N (4.51), S(10.33), HRMS (C_{42}H_{24}N_{2}S_{2} [M]+): calculated; 620.79, found; 619

Synthesis Example 6: Synthesis of Compound H-01

Int-7 (1eq), bromobenzene (1.2eq), Pd(dba)$_3$ (0.03eq), (t-Bu)$_3$P (0.06eq), and toluene (0.1M based on Int-7) were loaded into a flask, and then, the resulting mixture was reflux-stirred for 12 hours. Once the reaction was complete, the mixture was cooled to room temperature and subjected to an extraction process using methylene chloride, and the extraction result was washed with distilled water. A collected organic layer was dried by using MgSO$_4$ and distilled under reduced pressure to obtain the residual, which was then purified by column chromatography to obtain Compound H-01 (yield of 86.4%). Compound H-01 was identified by Elemental analysis and HRMS.

Elemental analysis (C_{39}H_{30}N_{2}): calculated; C(88.94), H (5.74), N (5.32), HRMS (C_{39}H_{30}N_{2} [M]+): calculated; 526.68, found; 525

Synthesis Example 7: Synthesis of Compound H-03

Compound H-03 (yield of 82.6%) was prepared in the same (or substantially the same) manner as in Synthesis Example 6, except that 1-bromo-2-methylbenzene was used instead of bromobenzene. Compound H-03 was identified by Elemental analysis and HRMS.

Elemental analysis (C_{40}H_{32}N_{2}): calculated; C(88.85), H (5.97), N (5.18), HRMS (C_{40}H_{32}N_{2} [M]+): calculated; 540.26, found; 539

Synthesis Example 8: Synthesis of Compound H-06

Compound H-06 (yield of 77.4%) was prepared in the same (or substantially the same) manner as in Synthesis Example 6, except that 2-bromonaphthalene was used instead of bromobenzene. Compound H-06 was identified by Elemental analysis and HRMS.

Elemental analysis (C_{43}H_{32}N_{2}): calculated; C(89.55), H (5.59), N (4.86), HRMS (C_{43}H_{32}N_{2} [M]+): calculated; 576.74, found; 575

Synthesis Example 9: Synthesis of Compound H-09

Compound H-09 (yield of 72.6%) was prepared in the same (or substantially the same) manner as in Synthesis Example 6, except that 3-bromo-9-phenyl-9H-carbazole was used instead of bromobenzene. Compound H-09 was identified by Elemental analysis and HRMS.

Elemental analysis (C_{51}H_{37}N_{3}): calculated; C(88.54), H (5.39), N (6.07), HRMS (C_{51}H_{37}N_{3} [M]+): calculated; 691.88, found; 690

Synthesis Example 10: Synthesis of Compound H-17

Compound H-17 (yield of 71.4%) was prepared in the same (or substantially the same) manner as in Synthesis Example 6, except that Int-8 was used instead of Int-7, and 3-bromo-9-phenyl-9H-carbazole was used instead of bromobenzene. Compound H-17 was identified by Elemental analysis and HRMS.

Elemental analysis (C_{55}H_{38}N_{2}): calculated; C(90.88), H (5.27), N (3.85), HRMS (C_{55}H_{38}N_{2} [M]+): calculated; 726.92, found; 725

Synthesis Example 11: Synthesis of Compound H-18

[0237]
Compound H-18 (yield of 72%) was prepared in the same (or substantially the same) manner as in Synthesis Example 6, except that N-([1,1′-biphenyl]-4-yl)-9-phenyl-9H-carbazole-3-amine was used instead of Int-7, and 2-(4-bromophenyl)-9,9-diphenyl-9H-fluorene was used instead of bromobenzene. Compound H-18 was identified by Elemental analysis and HRMS.

Elemental analysis (C_{61}H_{42}N_{2}): calculated; C(91.24), H (5.27), N (3.49), HRMS (C_{61}H_{42}N_{2} [M]+): calculated; 803.02, found; 802

Synthesis Example 12: Synthesis of Compound H-21

Compound H-21 (yield of 70.1%) was prepared in the same (or substantially the same) manner as in Synthesis Example 6, except that Int-8 was used instead of Int-7, and 3-(4-bromophenyl)-9-phenyl-9H-carbazole was used instead of bromobenzene. Compound H-21 was identified by Elemental analysis and HRMS.

Elemental analysis (C_{61}H_{42}N_{2}): calculated; C(91.24), H (5.27), N (3.49), HRMS (C_{61}H_{42}N_{2} [M]+): calculated; 803.02, found; 802

Synthesis Example 13: Synthesis of Compound H-27

Compound H-27 (yield of 73%) was prepared in the same (or substantially the same) manner as in Synthesis Example 6, except that Int-8 was used instead of Int-7, and 3-(4′-bromo-[1,1′-biphenyl]-3-yl)-9-phenyl-9H-carbazole was used instead of bromobenzene. Compound H-27 was identified by Elemental analysis and HRMS.

Elemental analysis (C_{67}H_{46}N_{2}): calculated; C(91.54), H (5.27), N (3.19), HRMS (C_{67}H_{46}N_{2} [M]+): calculated; 879.12, found; 878

Example 1

15Ω/cm² (500Å) ITO glass substrate available from Corning Inc. (as anode) was cut to a size of 50 mm x 50 mm x 0.5 mm and then sonicated with isopropyl alcohol and pure water, each for 10 minutes, and then, exposed to ultraviolet rays for 10 minutes, and then to ozone. The result was mounted on a vacuum deposition apparatus.

CBP and PD1 were co-deposited on the hole transport region at a weight ratio of 85:15 to form an emission layer having a thickness of 300 Å, and Alq3 was deposited on the emission layer to form an electron transport layer having a thickness of 300 Å, and Al was deposited on the electron transport layer to form an Al electrode (as cathode) having a thickness of 1,200 Å, thereby completing the manufacture of an organic light-emitting device.

Example 2 to 12 and Comparative Examples 1 to 3

Organic light-emitting devices were manufactured in the same (or substantially the same) manner as in Example 1, except that compounds as shown in Table 1 were used in forming the first layer and the second layer.
Evaluation Example

The efficiency and lifespan (at a current density of 300 mA/cm²) of the organic light-emitting devices of Examples 1 to 12 and Comparative Examples 1 to 3 were evaluated by using PR650 Source Measurement Unit (a product of PhotoResearch, Inc.). Results thereof are shown in Table 2. Herein, lifespan refers to a period of time that lapsed until the luminance of the organic light-emitting device was reduced to 95% of the initial luminance thereof:

<table>
<thead>
<tr>
<th>Table 2</th>
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<tbody>
<tr>
<td>Example</td>
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<td>Example 1</td>
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<td>Comparative Example 3</td>
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</tbody>
</table>
As shown in Table 2, the efficiency and lifespan of the organic light-emitting devices of Examples 1 to 12 were higher than those of the organic light-emitting devices of Comparative Examples 1 to 3.

An organic light-emitting device according to embodiments of the present inventive concept may have high efficiency and long lifespan.

It will be understood that if a substituent that appears in the present disclosure is not expressly defined above, the definition of the substituent is consistent with a general definition thereof, unless stated otherwise.

As used herein, the terms "use," "using," and "used" may be considered synonymous with the terms "utilize," "utilizing," and "utilized," respectively.

In addition, 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.

It should be understood that if a substituent that appears in the present disclosure is not expressly defined above, the definition of the substituent is consistent with a general definition thereof, unless stated otherwise.

As used herein, the terms "use," "using," and "used" may be considered synonymous with the terms "utilize," "utilizing," and "utilized," respectively.

In addition, 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.

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

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

While one or more embodiments of the invention have been described with reference to the figures, 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 scope of the present disclosure as defined by the following claims.

Claims

1. An organic light-emitting device comprising:
   a first electrode;
   a second electrode; and
   an organic layer between the first electrode and the second electrode, the organic layer comprising an emission layer and a hole transport region,
   wherein the hole transport region is between the first electrode and the emission layer, and
   the hole transport region comprises a first compound represented by Formula 1 and a second compound represented by Formula 2:

Formula 1

\[
\begin{align*}
\text{Formula 1} & \quad (R_{15})_{b_{15}} \\
\text{A}_{12} & \quad (L_{12})_{a_{12}} - R_{12} \quad n_{12} \\
\text{X}_{12} & \\
\text{A}_{13} & \quad (L_{13})_{a_{13}} \quad n_{13} \\
\text{R}_{13} & \quad (R_{13})_{b_{13}} \\
\text{A}_{11} & \quad (L_{11})_{a_{11}} \quad R_{11} \quad n_{11} \\
\text{X}_{11} & \quad (R_{11})_{b_{11}} \\
\text{A}_{10} & \quad (L_{10})_{a_{10}} \quad R_{10} \\
\text{X}_{10} & \quad (R_{10})_{b_{10}} \\
\text{A}_{9} & \quad (L_{19})_{a_{19}} \quad R_{19} \\
\text{X}_{9} & \quad (R_{19})_{b_{19}} \\
\text{A}_{8} & \quad (L_{18})_{a_{18}} \quad R_{18} \\
\text{X}_{8} & \quad (R_{18})_{b_{18}} \\
\text{A}_{7} & \quad (L_{17})_{a_{17}} \quad R_{17} \\
\text{X}_{7} & \quad (R_{17})_{b_{17}} \\
\text{A}_{6} & \quad (L_{16})_{a_{16}} \quad R_{16} \\
\text{X}_{6} & \quad (R_{16})_{b_{16}} \\
\text{A}_{5} & \quad (L_{15})_{a_{15}} \quad R_{15} \\
\text{X}_{5} & \quad (R_{15})_{b_{15}} \\
\text{A}_{1} & \quad (L_{1})_{a_{1}} \quad R_{1} \quad n_{1} \\
\end{align*}
\]
wherein, in Formulae 1 and 2,

- $X_{11}$ is selected from a single bond, N$(R_{17})$, P$(R_{17})$, C$(R_{17})(R_{18})$, Si$(R_{17})(R_{18})$, O, and S;
- $X_{12}$ is selected from a single bond, N$(R_{19})$, P$(R_{19})$, C$(R_{19})(R_{20})$, Si$(R_{19})(R_{20})$, O, and S,
- $X_{21}$ is selected from B, N, and P;
- $A_{11}$ to $A_{13}$ are each independently selected from a C$_5$-C$_{20}$ cyclic group and a C$_1$-C$_{20}$ heterocyclic group;
- $L_{11}$ to $L_{13}$ and $L_{21}$ to $L_{23}$ are each independently selected from a substituted or unsubstituted C$_3$-C$_{10}$ cycloalkylene group, a substituted or unsubstituted C$_1$-C$_{10}$ heterocycloalkylene group, a substituted or unsubstituted C$_3$-C$_{10}$ cycloalkenylene group, a substituted or unsubstituted C$_1$-C$_{10}$ heterocycloalkenylene group, a substituted or unsubstituted C$_6$-C$_{60}$ arylene group, a substituted or unsubstituted C$_1$-C$_{60}$ heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed C$_8$-C$_{60}$ polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed 8- to 60-membered heteropolycyclic group;
- $a_{11}$ to $a_{13}$ and $a_{21}$ to $a_{23}$ are each independently selected from 0, 1, 2, 3, 4, and 5;
- $R_{11}$ to $R_{13}$ and $R_{21}$ to $R_{23}$ are each independently selected from a substituted or unsubstituted C$_3$-C$_{10}$ cycloalkyl group, a substituted or unsubstituted C$_1$-C$_{10}$ heterocycloalkyl group, a substituted or unsubstituted C$_3$-C$_{10}$ cycloalkenyl group, a substituted or unsubstituted C$_1$-C$_{10}$ heterocycloalkenyl group, a substituted or unsubstituted C$_6$-C$_{60}$ aryl group, a substituted or unsubstituted C$_1$-C$_{60}$ heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed C$_3$-C$_{60}$ polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group;
- $R_{14}$ to $R_{16}$ are each independently 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 hydrazono 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$_{60}$ alkyloxy group, a substituted or unsubstituted C$_1$-C$_{60}$ alkoxy 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$_{60}$ heteroaryloxy group, a substituted or unsubstituted C$_1$-C$_{60}$ heterarylthio group, a substituted or unsubstituted monovalent non-aromatic condensed C$_3$-C$_{60}$ polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group;
- $R_{17}$ to $R_{20}$ 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 hydrazono 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$_{60}$ alkyloxy group, a substituted or unsubstituted C$_1$-C$_{60}$ alkoxy 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$_{60}$ heteroaryloxy group, a substituted or unsubstituted C$_1$-C$_{60}$ heterarylthio group, a substituted or unsubstituted monovalent non-aromatic condensed C$_3$-C$_{60}$ polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group;

2. The organic light-emitting device of claim 1, wherein
the hole transport region comprises a first layer and a second layer;
the second layer is between the first layer and the first electrode;
the first layer comprises the first compound, and
the second layer comprises the second compound.

3. The organic light-emitting device of claim 1 or 2, wherein
A11 to A13 are each independently selected from a benzene, a naphthalene, and a pyridine; preferably a benzene
and a naphthalene.

4. The organic light-emitting device of any one of the preceding claims, wherein
L11 to L13 and L21 to L23 are each independently a group represented by Formulae 3-1 to 3-19:

\[
\begin{align*}
&3-1 \quad 3-2 \quad 3-3 \quad 3-4 \quad 3-5 \quad 3-6 \\
&3-7 \quad 3-8 \quad 3-9 \quad 3-10 \\
&3-11 \quad 3-12 \quad 3-13 \quad 3-14 \quad 3-15 \\
&3-16 \quad 3-17 \quad 3-18 \quad 3-19
\end{align*}
\]

wherein, in Formulae 3-1 to 3-19,
X31 is selected from O, S, and C(R33)(R34);
R31 to R32 are each independently 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 carboxyl group or a salt thereof,
a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C1-C20 alkyl group, a C1-C20
alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a fluorine group, a benzofluoreryl group,
a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrene 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;
R33 to R34 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 carboxyl group
or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C1-C20 alkyl group,
a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a fluorine group, a benzofluoreryl group,
a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrene 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;
an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;
a31 is selected from 0, 1, 2, 3, and 4;
a32 is selected from 0, 1, 2, 3, 4, 5, and 6;
a33 is selected from 0, 1, 2, 3, 4, 5, 6, 7, and 8;
a34 is selected from 0, 1, 2, 3, 4, and 5;
a35 is selected from 0, 1, 2, and 3; and
* and *' are each independently a binding site to a neighboring atom; preferably wherein
(L11)a11, (L12)a12, (L13)a13, (L21)a21, (L22)a22, and (L23)a23 are each independently a group represented by any one
of Formulae 4-1 to 4-14:

5. The organic light-emitting device of any one of the preceding claims,
wherein
R11 to R13 and R21 to R23 are each independently selected from 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 fluorantheny group, a triphenylenyl group, a pyrenyl group, a chrysennyl 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 furanly group,
an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isooxazolyl
group, a pyridyl group, a pyrazinyl group, a pyrimidinyl group, an isodinolyl group, an indolyl group, an indazolyl
group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a benzoquino

* and *' are each independently a binding site to a neighboring atom.
an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a benzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, a thianthrenyl group, a phenoxythiophenyl group, and a dibenzodioxinyl group; and
a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, an indacenyl group, an acenaphthenyl group, a fluorenyl group, a spir fluoren group, a benzofluoren group, a dibenzofluoren group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylene group, a pyrenyl group, a chrysene group, a napthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenc group, a pentacenc group, a rubicenc group, a coronenc group, an ovenyl 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, a purinyl group, a quinolinyl group, an isoquinolinyl group, a carboxyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, a phenanthrenyl group, an anthracenyl group, a fluroanthynyl group, a phenoxythiophenyl group, and a dibenzodioxinyl group; and

6. The organic light-emitting device of claim 5, wherein

R11 to R13 and R21 to R23 are each independently selected from a phenyl group, a naphthyl group, a fluorenyl group, a dibenzofuranyl group, a benzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, a thianthrenyl group, a phenoxythiophenyl group, and a dibenzodioxinyl group; and

7. The organic light-emitting device of any one of the preceding claims, wherein

R11 to R13 and R21 to R23 are each independently selected from groups represented by Formulae 5-1 to 5-12:
wherein, in Formulae 5-1 to 5-12,
X51 is selected from a single bond, N(R54), C(R54)(R55), O, and S;
X52 is selected from N(R56), C(R56)(R57), O, and S;
R51 to R57 are each independently selected from:
deuterium, a cyano group, a C1-C20 alkyl group, a phenyl group, a naphthyl group, a fluorenyl group, and a carbazolyl group,
and R54 and R55 are optionally combined with each other to form a ring selected from a substituted or unsubstituted C3-C10 cycloalkyl group, a substituted or unsubstituted C1-C10 heterocycloalkyl group, a substituted or unsubstituted C2-C10 cycloalkenyl group, a substituted or unsubstituted C1-C10 heterocycloalkenyl group, a substituted or unsubstituted C6-C60 aryl group, a substituted or unsubstituted C1-C60 heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed C8-C60 polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group;
b51 is selected from 0, 1, 2, 3, 4, and 5;
b52 is selected from 0, 1, 2, 3, 4, 5, 6, and 7;
b53 is selected from 0, 1, and 3;
b54 is selected from 0, 1, 2, 3, and 4;
b55 is selected from 0, 1, 2, 3, 4, 5, and 6; and
* indicates a binding site to a neighboring atom.

8. The organic light-emitting device of any one of the preceding claims,
wherein
R14 to R16 are each independently 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 hydrazono group, a hydrozone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C1-C6 alkyl group, a C1-C60 alkoxy group, a C6-C60 aryl group, a C1-C60 heteroaryl group, a monovalent non-aromatic condensed C8-C60 polycyclic group, a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group, and -Si(Q1)(Q2)(Q3),
R17 to R20 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 hydrazono group, a hydrozone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C1-C60 alkyl group, a C1-C60 alkoxy group, a C6-C60 aryl group, a C1-C60 heteroaryl group, a monovalent non-aromatic condensed C8-C60 polycyclic group, a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group, and -Si(Q1)(Q2)(Q3),
R17 to R20 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 hydrazono group, a hydrozone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C1-C60 alkyl group, a C6-C60 alkoxy group, a C6-C60 aryl group, a C1-C60 heteroaryl group, a monovalent non-aromatic condensed C8-C60 polycyclic group, a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group, and -Si(Q1)(Q2)(Q3),
alkyl group, a C₁-C₆₀ alkoxy group, a C₆-C₆₀ aryl group, a C₁-C₆₀ heteroaryl group, a monovalent non-aromatic condensed C₆-C₆₀ polycyclic group, a monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group, and -Si(Q₁)(Q₂)(Q₃),

wherein Q₁ to Q₃ are each independently selected from a C₁-C₆₀ alkyl group and a C₆-C₆₀ aryl group.

9. The organic light-emitting device of any one of the preceding claims,

wherein

n₁₁ to n₁₃ are each independently selected from 0 and 1, and the sum of n₁₁ to n₁₃ is selected from 1 and 2.

10. The organic light-emitting device of any one of the preceding claims,

wherein

the compound represented by Formula 1 is represented by any one of Formulae 1-1 to 1-3;

preferably wherein the compound represented by Formula 1 is represented by any one of Formulae 1-21 to 1-31:

**Formulae 1-1 to 1-3**

![Diagram of Formulae 1-1 to 1-3]

**Formulae 1-21 to 1-31**
EP 3 133 661 A1

1-21

1-22

1-23

1-24

1-25

1-26
wherein, in Formulae 1-1 to 1-3 and 1-21 to 1-31, 
X_{11} is selected from N(R_{17}), P(R_{17}), P(R_{17})(R_{18}), C(R_{17})(R_{18}), Si(R_{17})(R_{18}), O, and S; and 
A_{11} to A_{13}, L_{11} to L_{13}, a_{11} to a_{13}, R_{11} to R_{13}, R_{14} to R_{18}, and b_{14} to b_{16} are as defined in any one of the preceding claims.

11. The organic light-emitting device of any one of the preceding claims, wherein 
the compound represented by Formula 1 is selected from Compounds A1 to A52:
The organic light-emitting device of any one of the preceding claims, wherein

the compound represented by Formula 2 is represented by Formula 2-1:

**Formula 2-1**

wherein, in Formula 2-1,

- $X_{21}$, $L_{21}$ to $L_{23}$, $a_{21}$ to $a_{23}$, $R_{22}$, and $R_{23}$ are as defined in any one of claims 1 and 4 to 7;
- $X_{22}$ is selected from $N(R_{203})$, $C(R_{203})(R_{204})$, $O$, and $S$;
- $R_{201}$ to $R_{202}$ are each independently 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 substituted or unsubstituted C1-C60 alkyl group, a substituted or unsubstituted C1-C60 alkoxy group, a substituted or unsubstituted C6-C60 aryl group, a substituted or unsubstituted C6-C60 aryloxy group, a substituted or unsubstituted C6-C60 arylthio group, a substituted or unsubstituted C1-C60 heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed C8-C60 polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group;

R203 to R204 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 C1-C60 alkyl group, a substituted or unsubstituted C1-C60 alkoxy group, a substituted or unsubstituted C6-C60 aryl group, a substituted or unsubstituted C6-C60 aryloxy group, a substituted or unsubstituted C6-C60 arylthio group, a substituted or unsubstituted C1-C60 heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed C8-C60 polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed 8- to 60-membered heteropolycyclic group;

b201 is selected from 0, 1, 2, and 3; and
b202 is selected from 0, 1, 2, 3, and 4.

13. The organic light-emitting device of claim 1, wherein
the compound represented by Formula 2 is represented by Formula 2-11; preferably wherein the compound represented by Formula 2 is represented by any one of Formulae 2-21 to 2-36;
more preferably wherein the compound represented by Formula 2 is represented by any one of Formulae 2-41 to 2-44:

**Formula 2-11**

[Diagram of a molecular structure with labels R203, R204, L21, L22, X21, X22, L23, R206, R207, R20, R202, and b201-b202 as specified in the text.]
Formulae 2-21 to 2-36
wherein, in Formulae 2-11, 2-21 to 2-36 and 2-41 to 2-44,
X_{21}, L_{21}, a_{21}, a_{23}, and R_{22} are as defined in any one of claims 1 and 4 to 7; X_{22} is selected from N(R_{203}), O, and S; R_{201} to R_{203}, R_{205}, R_{206} b_{201} and b_{202} are as defined in claim 12.

14. The organic light-emitting device of claim 1, wherein
   the compound represented by Formula 2 is selected from Compounds H-01 to H-36:
15. An organic light-emitting device comprising:

a substrate divided according to a first sub-pixel region, a second sub-pixel region, and a third sub-pixel region;
at least one electrode in each of the first sub-pixel region, the second sub-pixel region, and the third sub-pixel region of the substrate, the electrodes in the first, second and third sub-pixel regions together forming a plurality of first electrodes;
a second electrode facing the plurality of first electrodes; and
an organic layer between the second electrode and the plurality of first electrodes, the organic layer comprising an emission layer and a hole transport region;
wherein the hole transport region is between the emission layer and the plurality of first electrodes; and
the hole transport region comprises a first compound represented by Formula 1 and a second compound represented by Formula 2;
wherein the compounds of Formulae 1 and 2 are as defined in any one of claims 1 and 3 to 14.
FIG. 1

190
150
110
# DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<tr>
<th>Category</th>
<th>Citation of document with indication, where appropriate, of relevant passages</th>
<th>Relevant to claim</th>
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The present search report has been drawn up for all claims

**Place of search** | **Date of completion of the search** | **Examiner**
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The Hague | 2 January 2017 | Wolfbauer, Georg

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