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Ink composition, organic light-emitting device using the ink composition, and method of manufacturing organic light-emitting device using the ink composition

Abstract

Provided are an ink composition, an organic light-emitting device using the ink composition, and a method of manufacturing an organic light-emitting device using the ink composition. The ink composition contains a compound represented by Formula 1, an amine-based compound, and a polar solvent: ##STR00001## wherein, in Formula 1, L.sub.1 and L.sub.2 are each independently a substituted or unsubstituted C.sub.5-C.sub.60 carbocyclic group or a substituted or unsubstituted C.sub.1-C.sub.60 heterocyclic group. Details about the compound of Formula 1, the amine-based compound, and the polar solvent are provided.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION

(1) This application claims the benefit of Korean Patent Application No. 10-2016-0146913 filed on Nov. 4, 2016 in the Korean Intellectual Property Office, the disclosure of which is incorporated herein in its entirety by reference.

BACKGROUND

1. Field

(2) One or more embodiments relate to an ink composition, an organic light-emitting device using

the ink composition, and a method of manufacturing an organic light-emitting device using the ink composition.

2. Description of the Related Art

(3) Organic light-emitting devices are self-emission devices that produce full-color images, and also have wide viewing angles, high contrast ratios, short response times, and excellent characteristics in terms of brightness, driving voltage, and response speed, compared to devices in the art.

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

SUMMARY

(5) Aspects of the present disclosure provide an ink composition, an organic light-emitting device using the ink composition, and a method of manufacturing an organic light-emitting device using the ink composition.

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

(7) An aspect provides an ink composition including a compound represented by Formula 1 below, an amine-based compound, and a polar solvent:

(8) ##STR00002##

(9) In Formula 1, L.sub.1 and L.sub.2 may each independently be a substituted or unsubstituted C.sub.5-C.sub.60 carbocyclic group or a substituted or unsubstituted C.sub.1-C.sub.60 heterocyclic group, R.sub.1 to R.sub.10 may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), a substituted or unsubstituted C.sub.1-C.sub.60 alkyl group, a substituted or unsubstituted C.sub.2-C.sub.60 alkenyl group, a substituted or unsubstituted C.sub.2-C.sub.60 alkynyl group, a substituted or unsubstituted C.sub.1-C.sub.60 alkoxy group, a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkyl group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkyl group, a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkenyl group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkenyl group, a substituted or unsubstituted C.sub.6-C.sub.60 aryl group, a substituted or unsubstituted C.sub.6-C.sub.60 aryloxy group, a substituted or unsubstituted C.sub.6-C.sub.60 arylthio group, a substituted or unsubstituted C.sub.1-C.sub.60 heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, at least one of R.sub.3 to R.sub.10 may be selected from deuterium, a C.sub.1-C.sub.10 alkyl group, and —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), a1 and a2 may each independently be an integer from 1 to 5, b1 and b2 may each independently be an integer from 1 to 5, at least one substituent of the substituted C.sub.5-C.sub.60 carbocyclic group, the substituted C.sub.1-C.sub.60 heterocyclic group, the substituted C.sub.1-C.sub.60 alkyl group, the substituted C.sub.2-C.sub.60 alkenyl group, the substituted C.sub.2-C.sub.60 alkynyl group, the substituted C.sub.1-C.sub.60 alkoxy group, the substituted C.sub.3-C.sub.10 cycloalkyl group, the substituted C.sub.1-C.sub.10 heterocycloalkyl group, the substituted C.sub.3-C.sub.10 cycloalkenyl group, the substituted C.sub.1-C.sub.10 heterocycloalkenyl group, the substituted C.sub.6-C.sub.60 aryl group, the substituted C.sub.6-C.sub.60 aryloxy group, the substituted C.sub.6-C.sub.60 arylthio group, the substituted C.sub.1-C.sub.60 heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from: deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro

group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.60 alkyl group, a C.sub.2-C.sub.60 alkenyl group, a C.sub.2-C.sub.60 alkynyl group, and a C.sub.1-C.sub.60 alkoxy group; a C.sub.1-C.sub.60 alkyl group, a C.sub.2-C.sub.60 alkenyl group, a C.sub.2-C.sub.60 alkynyl group, and a C.sub.1-C.sub.60 alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.1-C.sub.10 heterocycloalkyl group, a C.sub.3-C.sub.10 cycloalkenyl group, a C.sub.1-C.sub.10 heterocycloalkenyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.6-C.sub.60 aryloxy group, a C.sub.6-C.sub.60 arylthio group, a C.sub.1-C.sub.60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group; a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.1-C.sub.10 heterocycloalkyl group, a C.sub.3-C.sub.10 cycloalkenyl group, a C.sub.1-C.sub.10 heterocycloalkenyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.6-C.sub.60 aryloxy group, a C.sub.6-C.sub.60 arylthio group, a C.sub.1-C.sub.60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group; a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.1-C.sub.10 heterocycloalkyl group, a C.sub.3-C.sub.10 cycloalkenyl group, a C.sub.1-C.sub.10 heterocycloalkenyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.6-C.sub.60 aryloxy group, a C.sub.6-C.sub.60 arylthio group, a C.sub.1-C.sub.60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.60 alkyl group, a C.sub.2-C.sub.60 alkenyl group, a C.sub.2-C.sub.60 alkynyl group, a C.sub.1-C.sub.60 alkoxy group, a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.1-C.sub.10 heterocycloalkyl group, a C.sub.3-C.sub.10 cycloalkenyl group, a C.sub.1-C.sub.10 heterocycloalkenyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.6-C.sub.60 aryloxy group, a C.sub.6-C.sub.60 arylthio group, a C.sub.1-C.sub.60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group; and —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), —N(Q.sub.31)(Q.sub.32), —B(Q.sub.31)(Q.sub.32), —C(═O)(Q.sub.31), —S(═O).sub.2(Q.sub.31), and —P(═O)(Q.sub.31)(Q.sub.32), and Q.sub.1 to Q.sub.3, Q.sub.11 to Q.sub.13, Q.sub.21 to Q.sub.23, and Q.sub.31 to Q.sub.33 may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.60 alkyl group, a C.sub.2-C.sub.60 alkenyl group, a C.sub.2-C.sub.60 alkynyl group, a C.sub.1-C.sub.60 alkoxy group, a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.1-C.sub.10 heterocycloalkyl group, a C.sub.3-C.sub.10 cycloalkenyl group, a C.sub.1-C.sub.10 heterocycloalkenyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.6-C.sub.60 aryl group substituted with a C.sub.1-C.sub.60 alkyl group, a C.sub.1-C.sub.60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

(10) Another aspect provides an organic light-emitting device including: a first electrode; a second electrode facing the first electrode; and an organic layer that is disposed between the first electrode and the second electrode and includes an emission layer, wherein the organic layer is formed by using the ink composition described above.

(11) Another aspect provides a method of manufacturing an organic light-emitting device, the method including forming an organic layer that is disposed between a first electrode and a second electrode and includes an emission layer, wherein the forming of the organic layer includes performing a solution process using the ink composition described above.

Description

BRIEF DESCRIPTION OF THE DRAWING

(1) These and/or other aspects will become apparent and more readily appreciated from the following description of the embodiments, taken in conjunction with the FIGURE which is a schematic view of an organic light-emitting device according to an embodiment.

DETAILED DESCRIPTION

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

(3) An ink composition according to an embodiment includes a compound represented by Formula 1, an amine-based compound, and a polar solvent:

(4) ##STR00003##

(5) In one embodiment, the compound of Formula 1 and the amine-based compound are dissolved in the polar solvent.

(6) In one embodiment, L.sub.1 and L.sub.2 in Formula 1 may each independently be a substituted or unsubstituted C.sub.5-C.sub.60 carbocyclic group or a substituted or unsubstituted C.sub.1-C.sub.60 heterocyclic group.

(7) In one embodiment, L.sub.1 and L.sub.2 may each independently be selected from: a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a naphthofluorene group, a carbazole group, a dibenzofuran group, a benzonaphthofuran group, a dibenzothiophene group, a benzocarbazole group, and a dibenzocarbazole group; and a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a naphthofluorene group, a carbazole group, a dibenzofuran group, a benzonaphthofuran group, a dibenzothiophene group, a benzocarbazole group, and a dibenzocarbazole group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a C.sub.1-C.sub.20 alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a carbazolyl group, a dibenzofuranyl group, a benzonaphthofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group.

(8) In one embodiment, L.sub.1 and L.sub.2 may each independently be selected from: a benzene group, a naphthalene group, a fluorene group, a carbazole group, a dibenzofuran group, and a benzonaphthofuran group; and a benzene group, a naphthalene group, a fluorene group, a carbazole group, a dibenzofuran group, and a benzonaphthofuran group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a phenyl group, a naphthyl group, a fluorenyl group, a carbazolyl group, a dibenzofuranyl group, a benzonaphthofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group.

(9) In one embodiment, R.sub.1 to R.sub.10 in Formula 1 may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), a substituted or unsubstituted C.sub.1-C.sub.60 alkyl group, a

substituted or unsubstituted C.sub.2-C.sub.60 alkenyl group, a substituted or unsubstituted C.sub.2-C.sub.60 alkynyl group, a substituted or unsubstituted C.sub.1-C.sub.60 alkoxy group, a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkyl group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkyl group, a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkenyl group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkenyl group, a substituted or unsubstituted C.sub.6-C.sub.60 aryl group, a substituted or unsubstituted C.sub.6-C.sub.60 aryloxy group, a substituted or unsubstituted C.sub.6-C.sub.60 arylthio group, a substituted or unsubstituted C.sub.1-C.sub.60 heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group.

(10) In one embodiment, R.sub.1 to R.sub.10 may each independently be selected from: hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a C.sub.1-C.sub.20 alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-fluorene-benzofluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a biphenylyl group; and —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, and a hexyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-fluorene-benzofluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a biphenylyl group.

(11) In one embodiment, R.sub.1 to R.sub.10 may each independently be selected from: hydrogen, deuterium, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, and a hexyl group; and a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, and a hexyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, and a hexyl group.

(12) In one embodiment, at least one of R.sub.4, R.sub.5, R.sub.8, and R.sub.9 in Formula 1 may be selected from deuterium, a C.sub.1-C.sub.10 alkyl group, and —Si(Q.sub.31)(Q.sub.32)(Q.sub.33).

(13) In one embodiment, R.sub.4 and R.sub.9 or R.sub.5 and R.sub.8 in Formula 1 may each independently be selected from deuterium, a methyl group, an ethyl group, a propyl group, an

isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a trimethylsilyl group, a triethylsilyl group, and a tributylsilyl group.
(14) In one embodiment, R.sub.1 and R.sub.2 in Formula 1 may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), a substituted or unsubstituted C.sub.1-C.sub.60 alkyl group, a substituted or unsubstituted C.sub.2-C.sub.60 alkenyl group, a substituted or unsubstituted C.sub.2-C.sub.60 alkynyl group, and a substituted or unsubstituted C.sub.1-C.sub.60 alkoxy group.
(15) In one embodiment, R.sub.3 to R.sub.10 in Formula 1 may each independently be selected from: hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a C.sub.1-C.sub.20 alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-fluorene-benzofluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a biphenylyl group; and —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, and a hexyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-fluorene-benzofluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a biphenylyl group.
(16) In one embodiment, R.sub.3 to R.sub.10 in Formula 1 may each independently be selected from: hydrogen, deuterium, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, and a hexyl group; and a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, and a hexyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, and a hexyl group.
(17) In one embodiment, *-(L.sub.1).sub.a1-(R.sub.1).sub.b1 and *-(L.sub.2).sub.a2-(R.sub.2).sub.b2 may each independently be selected from groups represented by Formulae 1-1 to 1-15:
(18) ##STR00004## ##STR00005##
(19) In Formulae 1-1 to 1-15, * indicates a binding site to a neighboring atom.
(20) In one embodiment, the compound represented by Formula 1 may be selected from Compounds 1 to 45:
(21) ##STR00006## ##STR00007## ##STR00008## ##STR00009## ##STR00010##

##STR00011## ##STR00012## ##STR00013## ##STR00014## ##STR00015##
(22) In the compound represented by Formula 1, a position that can react with the solvent in the ink composition is substituted with a substituent other than hydrogen. Thus, when an organic light-emitting device is manufactured using the ink composition, a side reaction with the solvent is prevented to enhance storage stability of the ink composition, thereby obtaining the effect of improving the efficiency and lifespan of the organic light-emitting device.
(23) In one embodiment, the amine-based compound may be represented by Formula 2 below:
(24) ##STR00016##
(25) In one embodiment, L.sub.11, L.sub.12, and L.sub.21 to L.sub.24 in Formula 2 may each independently be a substituted or unsubstituted C.sub.5-C.sub.60 carbocyclic group or a substituted or unsubstituted C.sub.1-C.sub.60 heterocyclic group.
(26) In one embodiment, L.sub.11, L.sub.12, and L.sub.21 to L.sub.24 may each independently be selected from: a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a naphthofluorene group, a carbazole group, a dibenzofuran group, a benzonaphthofuran group, a dibenzothiophene group, a benzocarbazole group, and a dibenzocarbazole group; and a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a naphthofluorene group, a carbazole group, a dibenzofuran group, a benzonaphthofuran group, a dibenzothiophene group, a benzocarbazole group, and a dibenzocarbazole group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a C.sub.1-C.sub.20 alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a carbazolyl group, a dibenzofuranyl group, a benzonaphthofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group.
(27) In one embodiment, L.sub.11, L.sub.12, and L.sub.21 to L.sub.24 may each independently be selected from: a benzene group, a naphthalene group, a fluorene group, a carbazole group, a dibenzofuran group, and a benzonaphthofuran group; and a benzene group, a naphthalene group, a fluorene group, a carbazole group, a dibenzofuran group, and a benzonaphthofuran group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a phenyl group, a naphthyl group, a fluorenyl group, a carbazolyl group, a dibenzofuranyl group, a benzonaphthofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group.
(28) In one embodiment, R.sub.11 to R.sub.22 in Formula 2 may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), a substituted or unsubstituted C.sub.1-C.sub.60 alkyl group, a substituted or unsubstituted C.sub.2-C.sub.60 alkenyl group, a substituted or unsubstituted C.sub.2-C.sub.60 alkynyl group, a substituted or unsubstituted C.sub.1-C.sub.60 alkoxy group, a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkyl group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkyl group, a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkenyl group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkenyl group, a substituted or unsubstituted C.sub.6-C.sub.60 aryl group, a substituted or unsubstituted C.sub.6-C.sub.60 aryloxy group, a substituted or unsubstituted C.sub.6-C.sub.60 arylthio group, a substituted or unsubstituted C.sub.1-C.sub.60 heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group.
(29) In one embodiment, R.sub.11 to R.sub.22 may each independently be selected from: hydrogen,

deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a C.sub.1-C.sub.20 alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-fluorene-benzofluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a biphenylyl group; and —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, and a hexyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-fluorene-benzofluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a biphenylyl group.

(30) In one embodiment, R.sub.11 to R.sub.22 may each independently be selected from: hydrogen, deuterium, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, and a hexyl group; and a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, and a hexyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, and a hexyl group.

(31) In one embodiment, at least one of R.sub.15 to R.sub.22 in Formula 2 may be selected from deuterium, a C.sub.1-C.sub.10 alkyl group, and —Si(Q.sub.31)(Q.sub.32)(Q.sub.33).

(32) In one embodiment, at least one of R.sub.15 to R.sub.22 in Formula 2 may be selected from deuterium, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a trimethylsilyl group, a triethylsilyl group, and a tributylsilyl group.

(33) In one embodiment, R.sub.11 to R.sub.14 in Formula 1 may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), a substituted or unsubstituted C.sub.1-C.sub.60 alkyl group, a substituted or unsubstituted C.sub.2-C.sub.60 alkenyl group, a substituted or unsubstituted C.sub.2-C.sub.60 alkynyl group, and a substituted or unsubstituted C.sub.1-C.sub.60 alkoxy group.

(34) In one embodiment, R.sub.15 to R.sub.22 in Formula 2 may each independently be selected from: hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a C.sub.1-C.sub.20 alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a

cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-fluorene-benzofluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthndinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a biphenylyl group; and —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, and a hexyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-fluorene-benzofluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a biphenylyl group.

(35) In one embodiment, R.sub.15 to R.sub.22 in Formula 1 may each independently be selected from: hydrogen, deuterium, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, and a hexyl group; and a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, and a hexyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, and a hexyl group.

(36) In one embodiment, at least one of R.sub.17 and R.sub.21 may be selected from deuterium, a C.sub.1-C.sub.10 alkyl group, and —Si(Q.sub.31)(Q.sub.32)(Q.sub.33).

(37) In one embodiment, R.sub.17 and R.sub.21 may each independently be selected from hydrogen, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a trimethylsilyl group, a triethylsilyl group, and a tributylsilyl group.

(38) In one embodiment, a11 and a12 in Formula 2 may each independently be an integer from 0 to 5.

(39) In one embodiment, a11 and a12 may each independently be 0, 1, or 2.

(40) In one embodiment, a11 may be 0 or 1.

(41) In one embodiment, a11 may be 0.

(42) In one embodiment, a11 may be 1.

(43) In one embodiment, a12 may be 0 or 1.

(44) In one embodiment, a12 may be 0.

(45) In one embodiment, a12 may be 1.

(46) In one embodiment, a21 to a24 in Formula 2 may each independently be 0 or 1.

(47) In one embodiment, a21 may be 0.

(48) In one embodiment, a21 may be 1.

(49) In one embodiment, a22 may be 0.

(50) In one embodiment, a22 may be 1.

(51) In one embodiment, a23 may be 0.
(52) In one embodiment, a23 may be 1.
(53) In one embodiment, a24 may be 0.
(54) In one embodiment, a24 may be 1.
(55) In one embodiment, b11 to b14 in Formula 2 may each independently be an integer from 1 to 5.
(56) In one embodiment, b11 and b14 may each independently be 1 or 2.
(57) In one embodiment, b11 and b14 may each independently be 3, 4, or 5.
(58) In one embodiment, *-(L.sub.21).sub.a21-(R.sub.11).sub.b11, *-(L.sub.22).sub.a22-(R.sub.12).sub.b12, *-(L.sub.23).sub.a23-(R.sub.13).sub.b13, and *-(L.sub.24).sub.a24-(R.sub.14).sub.b14 may each independently be selected from groups represented by Formulae 2-1 to 2-4:
(59) ##STR00017##
(60) In Formulae 2-1 to 2-4, * indicates a binding site to a neighboring atom.
(61) In one embodiment, the amine-based compound may be selected from Compounds 101 to 110:
(62) ##STR00018## ##STR00019## ##STR00020##
(63) In the compound represented by Formula 2, a position that can react with the solvent in the ink composition is substituted with a substituent other than hydrogen. Thus, when an organic light-emitting device is manufactured using the ink composition, a side reaction with the solvent is prevented to enhance storage stability of the ink composition, thereby obtaining the effect of improving the efficiency and lifespan of the organic light-emitting device.
(64) In one embodiment, a relative polarity of the polar solvent may be in a range of about 0.2 to about 0.4. When the polar solvent satisfying the relative polarity range, a solubility of ink may increase.
(65) In one embodiment, the polar solvent may be a C.sub.1-C.sub.10 alkyl benzoate.
(66) In one embodiment, the polar solvent may be selected from a methyl benzoate, an ethyl benzoate, an n-propyl benzoate, an iso-propyl benzoate, and a t-butyl benzoate.
(67) In one embodiment, a solubility of the compound represented by Formula 1 in the polar solvent may be in a range of about 1% to about 10%, and a solubility of the compound represented by Formula 2 in the polar solvent may be in a range of about 0.01% to about 2%.
(68) In one embodiment, the ink composition may include about 1 part by weight to about 10 parts by weight of the compound represented by Formula 1, about 0.01 parts by weight to about 2 parts by weight of the compound represented by Formula 2, and about 90 parts by weight to about 99 parts by weight of the polar solvent.
(69) In one embodiment, provided is an organic light-emitting device including: a first electrode; a second electrode facing the first electrode; and an organic layer that is disposed between the first electrode and the second electrode and includes an emission layer, wherein the organic layer is formed by using the ink composition described above.
(70) In one embodiment, the first electrode may be an anode, and the second electrode may be a cathode.
(71) In one embodiment, the organic layer may further include a hole transport region between the first electrode and the emission layer, and an electron transport region between the emission layer and the second electrode.
(72) In one embodiment, the hole transport region may include at least one layer selected from a hole injection layer, a hole transport layer, an emission auxiliary layer, and an electron blocking layer.
(73) In one embodiment, the electron transport region may include at least one selected from a hole blocking layer, an electron transport layer, and an electron injection layer.
(74) In one embodiment, the emission layer includes a host and a dopant, the host may include a compound represented by Formula 1, and the dopant may include a compound represented by

Formula 2.
(75) In one embodiment, the host may include at least one selected from an anthracene-based compound, a pyrene-based compound, a spiro-bifluorene-based compound, and a phosphine oxide-based compound.
(76) In one embodiment, the dopant may further include a phosphorescent dopant.
(77) In one embodiment, the emission layer may include a blue emission layer emitting blue fluorescence.
(78) In one embodiment, provided is a method of manufacturing an organic light-emitting device, the method including forming an organic layer that is disposed between a first electrode and a second electrode and includes an emission layer, wherein the forming of the organic layer includes performing a solution process using the ink composition described above.
(79) In one embodiment, the solution process may be spin coating, slot coating, dip coating, bar coating, roll coating, gravure coating, micro gravure coating, wire coating, spray coating, ink-jet printing, nozzle printing, screen printing, flexo printing, offset printing, or casting.
(80) In one embodiment, in the forming of the organic layer, a thickness of the organic layer may be in a range of about 5 nm to about 60 nm. In one embodiment, the forming of the organic layer may further include evaporating the polar solvent.
(81) In one embodiment, the forming of the organic layer may further include evaporating the polar solvent, and the evaporating of the polar solvent is performed at a temperature of about 130° C. to about 160° C.
(82) The organic light-emitting device, which is manufactured by the above-described manufacturing method, uses the polar solvent, but substituents other than hydrogen are located at reactive positions of a first compound and a second compound. Thus, a side reaction with the solvent is prevented, and degeneration of the first compound and the second compound may be prevented accordingly.
(83) Therefore, an electronic device, for example, an organic light-emitting device, which is manufactured by the above-described manufacturing method, may have a low driving voltage, a high current density, and high efficiency.
(84) Specific conditions of the method of manufacturing the organic light-emitting device may be recognizable by those of ordinary skill by referring to Examples provided below, but embodiments of the present disclosure are not limited thereto.
(85) In addition to the compounds described above, other compounds known in the art may be used between a pair of electrodes of the organic light-emitting device. For example, other compounds may be included in at least one of the hole transport region and the emission layer. In one embodiment, other compounds may be used as a material for forming a capping layer disposed outside the pair of electrodes of the organic light-emitting device.
(86) Accordingly, provided is an organic light-emitting device including a first electrode; a second electrode facing the first electrode, and an organic layer that is disposed between the first electrode and the second electrode and includes at least one of the heterocyclic compound of Formula 1 described above.
(87) The expression “(an organic layer) includes at least one compound represented by Formula 1” used herein may include a case in which “(an organic layer) includes identical compounds represented by Formula 1” and a case in which “(an organic layer) includes two or more different compounds represented by Formula 1.”
(88) For example, the organic layer may include, as the heterocyclic compound, only Compound 1. In this regard, Compound 1 may exist in an emission layer of the organic light-emitting device. In one or more embodiments, the organic layer may include, as the heterocyclic compound, Compound 1 and Compound 2. In this regard, Compound 1 and Compound 2 may exist in an identical layer (for example, Compound 1 and Compound 2 may all exist in an emission layer), or different layers (for example, Compound 1 may exist in an emission layer and Compound 2 may

exist in an electron transport layer).
(89) According to one embodiment, the first electrode of the organic light-emitting device may be an anode, the second electrode of the organic light-emitting device may be a cathode, and the organic layer of the organic light-emitting device may further include a hole transport region between the first electrode and the emission layer and an electron transport region between the emission layer and the second electrode, the hole transport region may include at least one layer selected from a hole injection layer, a hole transport layer, a buffer layer, an emission auxiliary layer, and an electron blocking layer, and the electron transport region may include an electron transport region including at least one layer selected from a hole blocking layer, an electron transport layer, and an electron injection layer. The electron transport region may include the heterocyclic compound represented by Formula 1.
(90) In one embodiment, the electron transport region of the organic light-emitting device may include an electron transport layer and an electron injection layer, and at least one of the electron transport layer and the electron injection layer may include the heterocyclic compound represented by Formula 1. However, embodiments of the present disclosure are not limited thereto.
(91) In the organic light-emitting device, at least one layer selected from the electron transport layer and the electron injection layer may include an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare earth metal complex, or any combinations thereof.
(92) In the organic light-emitting device, the emission layer may include a dopant and a host, and the host may include at least one compound selected from an anthracene-based compound, a pyrene-based compound, and a spiro-bifluorene-based compound. In one embodiment, the dopant may include the first compound represented by Formula 1. In one or more embodiments, the dopant may include the second compound.
(93) The term “organic layer” used herein refers to a single layer and/or a plurality of layers disposed between the first electrode and the second electrode of an organic light-emitting device. A material included in the “organic layer” is not limited to an organic material.
(94) The FIGURE is a schematic view of an organic light-emitting device **10** according to an embodiment. The organic light-emitting device **10** includes a first electrode **110**, an organic layer **150**, and a second electrode **190**.
(95) Hereinafter, the structure of the organic light-emitting device **10** according to an embodiment and a method of manufacturing the organic light-emitting device **10** will be described in connection with the FIGURE.
(96) Referring to the FIGURE, a substrate may be additionally disposed under the first electrode **110** or above the second electrode **190**. The substrate may be a glass substrate or a plastic substrate, each having excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and water resistance.
(97) The first electrode **110** may be formed by depositing or sputtering a material for forming the first electrode **110** on the substrate. When the first electrode **110** is an anode, the material for forming the first electrode **110** may be selected from materials with a high work function to facilitate hole injection.
(98) The first electrode **110** may be a reflective electrode, a semi-transmissive electrode, or a transmissive electrode. When the first electrode **110** is a transmissive electrode, a material for forming a first electrode may be selected from indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO.sub.2), zinc oxide (ZnO), and any combinations thereof, but embodiments of the present disclosure are not limited thereto. In one or more embodiments, when the first electrode **110** is a semi-transmissive electrode or a reflectable electrode, a material for forming a first electrode may be selected from magnesium (Mg), silver (Ag), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), magnesium-silver (Mg—Ag), and any

combinations thereof, but embodiments of the present disclosure are not limited thereto.
(99) The first electrode **110** may have a single-layered structure, or a multi-layered structure including two or more layers. For example, the first electrode **110** may have a three-layered structure of ITO/Ag/ITO, but the structure of the first electrode **13** is not limited thereto.
(100) The organic layer **150** is disposed on the first electrode **110**. The organic layer **150** may include a first organic layer.
(101) In one embodiment, the organic layer **150** may include an emission layer. In one embodiment, the first organic layer includes an emission layer.
(102) In one embodiment, the organic layer **150** includes an electron transport region. The organic layer **150** includes a second organic layer between the first organic layer and the second electrode **190**. In detail, the second organic layer includes an electron transport region.
(103) The organic layer **150** may further include a hole transport region between the first electrode **110** and the emission layer. In one embodiment, the organic layer **150** may further include a hole transport region between the first electrode **110** and the emission layer and an electron transport region between the emission layer and the second electrode **190**.
(104) The hole transport region may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.
(105) The hole transport region may include at least one layer selected from a hole injection layer, a hole transport layer, an emission auxiliary layer, and an electron blocking layer.
(106) For example, the hole transport region may have a single-layered structure including a single layer including a plurality of different materials, or a multi-layered structure having a hole injection layer/hole transport layer structure, a hole injection layer/hole transport layer/emission auxiliary layer structure, a hole injection layer/emission auxiliary layer structure, a hole transport layer/emission auxiliary layer structure, or a hole injection layer/hole transport layer/electron blocking layer structure, wherein for each structure, constituting layers are sequentially stacked from the first electrode **110** in this stated order, but the structure of the hole transport region is not limited thereto.
(107) The hole transport region may include at least one selected from m-MTDATA, TDATA, 2-TNATA, NPB(NPD), β-NPB, TPD, Spiro-TPD, Spiro-NPB, methylated-NPB, TAPC, HMTPD, 4,4′,4″-tris(N-carbazolyl)triphenylamine (TCTA), polyaniline/dodecylbenzenesulfonic acid (PANI/DBSA), poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate) (PEDOT/PSS), polyaniline/camphor sulfonic acid (PANI/CSA), polyaniline/poly(4-styrenesulfonate) (PANI/PSS), a compound represented by Formula 201, and a compound represented by Formula 202:
(108) ##STR00021## ##STR00022## ##STR00023##
(109) In Formulae 201 and 202, L.sub.201 to L.sub.204 may each independently be selected from a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkylene group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkylene group, a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkenylene group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkenylene group, a substituted or unsubstituted C.sub.6-C.sub.60 arylene group, a substituted or unsubstituted C.sub.1-C.sub.60 heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group, L.sub.205 may be selected from *—O—*′, *—S—*′, *—N(Q.sub.201)-*′, a substituted or unsubstituted C.sub.1-C.sub.20 alkylene group, a substituted or unsubstituted C.sub.2-C.sub.20 alkenylene group, a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkylene group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkylene group, a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkenylene group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkenylene group, a substituted or unsubstituted C.sub.6-C.sub.60 arylene group, a substituted or unsubstituted C.sub.1-C.sub.60 heteroarylene group, a substituted or

unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group, xa1 to xa4 may each independently be an integer from 0 to 3, xa5 may be an integer from 1 to 10, and R.sub.201 to R.sub.204 and Q.sub.201 may each independently be selected from a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkyl group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkyl group, a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkenyl group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkenyl group, a substituted or unsubstituted C.sub.6-C.sub.60 aryl group, a substituted or unsubstituted C.sub.6-C.sub.60 aryloxy group, a substituted or unsubstituted C.sub.6-C.sub.60 arylthio group, a substituted or unsubstituted C.sub.1-C.sub.60 heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group.

(110) In one embodiment, in Formula 202, R.sub.201 and R.sub.202 may optionally be linked via a single bond, a dimethyl-methylene group, or a diphenyl-methylene group, and R.sub.203 and R.sub.204 may optionally be linked via a single bond, a dimethyl-methylene group, or a diphenyl-methylene group.

(111) In one or more embodiments, in Formulae 201 and 202, L.sub.201 to L.sub.205 may each independently be selected from: a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an indacenylene group, an acenaphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a rubicenylene group, a coronenylene group, an ovalenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, and a pyridinylene group; and a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an indacenylene group, an acenaphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a rubicenylene group, a coronenylene group, an ovalenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, and a pyridinylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.20 alkyl group, a C.sub.1-C.sub.20 alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C.sub.1-C.sub.10 alkyl group, a phenyl group substituted with —F, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an

indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), and —N(Q.sub.31)(Q.sub.32), and Q.sub.31 to Q.sub.33 may each independently be selected from a C.sub.1-C.sub.10 alkyl group, a C.sub.1-C.sub.10 alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

(112) In one or more embodiments, xa1 to xa4 may each independently be 0, 1, or 2.

(113) In one or more embodiments, xa5 may be 1, 2, 3, or 4.

(114) In one or more embodiments, R.sub.201 to R.sub.204 and Q.sub.201 may each independently be selected from: a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group; and a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.20 alkyl group, a C.sub.1-C.sub.20 alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C.sub.1-C.sub.10 alkyl group, a phenyl group substituted with —F, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), and —N(Q.sub.31)(Q.sub.32), and Q.sub.31 to Q.sub.33 are the same as described herein.

(115) In one or more embodiments, at least one of R.sub.201 to R.sub.203 in Formula 201 may be selected from: a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.20 alkyl group, a

C.sub.1-C.sub.20 alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C.sub.1-C.sub.10 alkyl group, a phenyl group substituted with —F, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, but embodiments of the present disclosure are not limited thereto.

(116) In one or more embodiments, in Formula 202, i) R.sub.201 and R.sub.202 may be linked via a single bond, and/or ii) R.sub.203 and R.sub.204 may be linked via a single bond.

(117) In one or more embodiments, at least one of R.sub.201 to R.sub.204 in Formula 202 may be selected from: a carbazolyl group; and a carbazolyl group substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.20 alkyl group, a C.sub.1-C.sub.20 alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C.sub.1-C.sub.10 alkyl group, a phenyl group substituted with —F, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, but embodiments of the present disclosure are not limited thereto.

(118) The compound represented by Formula 201 may be represented by Formula 201A:

(119) ##STR00024##

(120) In one embodiment, the compound represented by Formula 201 may be represented by Formula 201A(1) below, but embodiments of the present disclosure are not limited thereto:

(121) ##STR00025##

(122) In one embodiment, the compound represented by Formula 201 may be represented by Formula 201A-1 below, but embodiments of the present disclosure are not limited thereto:

(123) ##STR00026##

(124) In one embodiment, the compound represented by Formula 202 may be represented by Formula 202A:

(125) ##STR00027##

(126) In one embodiment, the compound represented by Formula 202 may be represented by Formula 202A-1:

(127) ##STR00028##

(128) In Formulae 201A, 201A(1), 201A-1, 202A, and 202A-1, L.sub.201 to L.sub.203, xa1 to xa3, xa5, and R.sub.202 to R.sub.204 are the same as described herein, R.sub.211 and R.sub.212 are the same as described in connection with R.sub.203, and R.sub.213 to R.sub.217 may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.20 alkyl group, a C.sub.1-C.sub.20 alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C.sub.1-C.sub.10 alkyl group, a phenyl group substituted with —F, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group.

(129) The hole transport region may include at least one compound selected from Compounds HT1 to HT39, but embodiments of the present disclosure are not limited thereto:

(130) ##STR00029## ##STR00030## ##STR00031## ##STR00032## ##STR00033## ##STR00034## ##STR00035##
(131) A thickness of the hole transport region may be in a range of about 100 Å to about 10,000 Å, for example, about 100 Å to about 1,000 Å. When the hole transport region includes at least one of a hole injection layer and a hole transport layer, a thickness of the hole injection layer may be in a range of about 100 Å to about 9,000 Å, for example, about 100 Å to about 1,000 Å, and a thickness of the hole transport layer may be in a range of about 50 Å to about 2,000 Å, for example about 100 Å to about 1,500 Å. When the thicknesses of the hole transport region, the hole injection layer, and the hole transport layer are within these ranges, satisfactory hole transporting characteristics may be obtained without a substantial increase in driving voltage.
(132) The emission auxiliary layer may increase light-emission efficiency by compensating for an optical resonance distance according to the wavelength of light emitted by an emission layer, and the electron blocking layer may block the flow of electrons from an electron transport region. The emission auxiliary layer and the electron blocking layer may include the materials as described above.
(133) The hole transport region may further include, in addition to these materials, a charge-generation material for the improvement of conductive properties. The charge-generation material may be homogeneously or non-homogeneously dispersed in the hole transport region.
(134) The charge-generation material may be, for example, a p-dopant.
(135) In one embodiment, the p-dopant may have a lowest unoccupied molecular orbital (LUMO) of about −3.5 eV or less.
(136) The p-dopant may include at least one selected from a quinone derivative, a metal oxide, and a cyano group-containing compound, but embodiments of the present disclosure are not limited thereto.
(137) For example, the p-dopant may include at least one selected from: a quinone derivative, such as tetracyanoquinodimethane (TCNQ) or 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F4-TCNQ);
(138) a metal oxide, such as tungsten oxide or molybdenum oxide; 1,4,5,8,9,11-hexaazatriphenylene-hexacarbonitrile (HAT-CN); and a compound represented by Formula 221 below: but embodiments of the present disclosure are not limited thereto:
(139) ##STR00036##
(140) In Formula 221, R.sub.221 to R.sub.223 may each independently be selected from a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkyl group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkyl group, a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkenyl group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkenyl group, a substituted or unsubstituted C.sub.6-C.sub.60 aryl group, a substituted or unsubstituted C.sub.1-C.sub.60 heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, provided that at least one of R.sub.221 to R.sub.223 has at least one substituent selected from a cyano group, —F, —Cl, —Br, —I, a C.sub.1-C.sub.20 alkyl group substituted with —F, a C.sub.1-C.sub.20 alkyl group substituted with —Cl, a C.sub.1-C.sub.20 alkyl group substituted with —Br, and a C.sub.1-C.sub.20 alkyl group substituted with —I.
(141) 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 one or more embodiments, the emission layer may have a stacked structure of two or more layers selected from a red emission layer, a green emission layer, and a blue emission layer, in which the two or more layers contact each other or are separated from each other. In one or more embodiments, the emission layer may include two or more materials selected from a red light-emitting material, a green light-emitting material, and a blue light-emitting material, in which the two or more materials are mixed with each other in a single layer to

emit white light.
(142) The emission layer may include a host and a dopant. The dopant may include at least one selected from a phosphorescent dopant and a fluorescent dopant. In one embodiment, the dopant may include the second compound represented by Formula 2. In one embodiment, the dopant may include the second compound represented by Formula 2 as a fluorescent dopant.
(143) The amount of the dopant in the emission layer may be typically in a range of about 0.01 parts by weight to about 15 parts by weight based on 100 parts by weight of the host, but embodiments of the present disclosure are not limited thereto.
(144) 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 this range, excellent light-emission characteristics may be obtained without a substantial increase in driving voltage.
(145) In one or more embodiments, the host may include a compound represented by Formula 301 below.
[Ar.sub.301].sub.xb11-[(L.sub.301).sub.xb1-R.sub.301].sub.xb21. <Formula 301>
(146) In Formula 301, Ar.sub.301 may be a substituted or unsubstituted C.sub.5-C.sub.60 carbocyclic group or a substituted or unsubstituted C.sub.1-C.sub.60 heterocyclic group, xb11 may be 1, 2, or 3, L.sub.301 may be selected from a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkylene group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkylene group, a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkenylene group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkenylene group, a substituted or unsubstituted C.sub.6-C.sub.60 arylene group, a substituted or unsubstituted C.sub.1-C.sub.60 heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group, xb1 may be an integer from 0 to 5, R.sub.301 may be selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C.sub.1-C.sub.60 alkyl group, a substituted or unsubstituted C.sub.2-C.sub.60 alkenyl group, a substituted or unsubstituted C.sub.2-C.sub.60 alkynyl group, a substituted or unsubstituted C.sub.1-C.sub.60 alkoxy group, a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkyl group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkyl group, a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkenyl group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkenyl group, a substituted or unsubstituted C.sub.6-C.sub.60 aryl group, a substituted or unsubstituted C.sub.6-C.sub.60 aryloxy group, a substituted or unsubstituted C.sub.6-C.sub.60 arylthio group, a substituted or unsubstituted C.sub.1-C.sub.60 heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(Q.sub.301)(Q.sub.302)(Q.sub.33), —N(Q.sub.301)(Q.sub.302), —B(Q.sub.301)(Q.sub.302), —C(═O)(Q.sub.301), —S(═O).sub.2(Q.sub.301), and —P(═O)(Q.sub.301)(Q.sub.302), xb21 may be an integer from 1 to 5, and Q.sub.301 to Q.sub.303 may each independently be selected from a C.sub.1-C.sub.10 alkyl group, a C.sub.1-C.sub.10 alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, but embodiments of the present disclosure are not limited thereto.
(147) In one embodiment, Ar.sub.301 in Formula 301 may be selected from: a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, and a dibenzothiophene group; and a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group,

a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, and a dibenzothiophene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.20 alkyl group, a C.sub.1-C.sub.20 alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), —N(Q.sub.31)(Q.sub.32), —B(Q.sub.31)(Q.sub.32), —C(═O)(Q.sub.31), —S(═O).sub.2(Q.sub.31), and —P(═O)(Q.sub.31)(Q.sub.32), and Q.sub.31 to Q.sub.33 may each independently be selected from a C.sub.1-C.sub.10 alkyl group, a C.sub.1-C.sub.10 alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, but embodiments of the present disclosure are not limited thereto.

(148) When xb11 in Formula 301 is two or more, two or more Ar.sub.301(s) may be linked via a single bond.

(149) In one or more embodiments, the compound represented by Formula 301 may be represented by Formula 301-1 or 301-2:

(150) ##STR00037##

(151) In Formulae 301-1 to 301-2, A.sub.301 to A.sub.304 may each independently be selected from a benzene, a naphthalene, a phenanthrene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a pyridine, a pyrimidine, an indene, a fluorene, a spiro-bifluorene, a benzofluorene, a dibenzofluorene, an indole, a carbazole, a benzocarbazole, a dibenzocarbazole, a furan, a benzofuran, a dibenzofuran, a naphthofuran, a benzonaphthofuran, a dinaphthofuran, a thiophene, a benzothiophene, a dibenzothiophene, a naphthothiophene, a benzonaphthothiophene, and a dinaphthothiophene, X.sub.301 may be O, S, or N-[(L.sub.304)).sub.xb4-R.sub.304], R.sub.311 to R.sub.314 may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.20 alkyl group, a C.sub.1-C.sub.20 alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), —N(Q.sub.31)(Q.sub.32), —B(Q.sub.31)(Q.sub.32), —C(═O)(Q.sub.31), —S(═O).sub.2(Q.sub.31), and —P(═O)(Q.sub.31)(Q.sub.32), xb22 and xb23 may each independently be 0, 1, or 2, L.sub.301, xb1, R.sub.301, and Q.sub.31 to Q.sub.33 are the same as described herein, L.sub.302 to L.sub.304 are each independently the same as described in connection with L.sub.301, Xb2 to xb4 are each independently the same as described in connection with xb1, R.sub.302 to R.sub.304 are each independently the same as described in connection with R.sub.301.

(152) For example, L.sub.301 to L.sub.304 in Formulae 301, 301-1, and 301-2 may each independently be selected from: a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, a pyridinylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isoxazolylene group, a thiadiazolylene group, an oxadiazolylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and

an azacarbazolylene group; and a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, a pyridinylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isoxazolylene group, a thiadiazolylene group, an oxadiazolylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.20 alkyl group, a C.sub.1-C.sub.20 alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an azacarbazolyl group, —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), —N(Q.sub.31)(Q.sub.32), —B(Q.sub.31)(Q.sub.32), —C(═O)(Q.sub.31), —S(═O).sub.2(Q.sub.31), and —P(═O)(Q.sub.31)(Q.sub.32), and Q.sub.31 to Q.sub.33 are the same as described herein.

(153) In one embodiment, R.sub.301 to R.sub.304 in Formulae 301, 301-1, and 301-2 may each independently be selected from: a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl

group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group; and a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.20 alkyl group, a C.sub.1-C.sub.20 alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an azacarbazolyl group, —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), —N(Q.sub.31)(Q.sub.32), —B(Q.sub.31)(Q.sub.32), —C(═O)(Q.sub.31), —S(═O).sub.2(Q.sub.31), and —P(═O)(Q.sub.31)(Q.sub.32), and Q.sub.31 to Q.sub.33 are the same as described herein.

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

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

(156) ##STR00038## ##STR00039## ##STR00040## ##STR00041## ##STR00042## ##STR00043## ##STR00044## ##STR00045## ##STR00046## ##STR00047## ##STR00048## ##STR00049##

(157) The phosphorescent dopant may include an organometallic complex represented by Formula

401 below:
(158) ##STR00050##
(159) In Formulae 401 and 402, M may be selected from iridium (Ir), platinum (Pt), palladium (Pd), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), rhodium (Rh), and thulium (Tm), L.sub.401 may be selected from ligands represented by Formula 402, and xc1 may be 1, 2, or 3, wherein, when xc1 is two or more, two or more L.sub.401(s) may be identical to or different from each other, L.sub.402 may be an organic ligand, and xc2 may be an integer from 0 to 4 wherein, when xc2 is two or more, two or more L.sub.402s may be identical to or different from each other, X.sub.401 to X.sub.404 may each independently be nitrogen or carbon, X.sub.401 and X.sub.403 may be linked via a single bond or a double bond, and X.sub.402 and X.sub.404 may be linked via a single bond or a double bond, A.sub.401 and A.sub.402 may each independently be a C.sub.5-C.sub.60 cyclic group or a C.sub.1-C.sub.60 heterocyclic group, X.sub.405 may be a single bond, *—O—*′, *—S—*′, *—C(═O)—*′, *—N(Q.sub.411)-*′, *—C(Q.sub.411)(Q.sub.412)-*′, *—C(Q.sub.411)═C(Q.sub.412)-*′, *—C(Q.sub.411)=*′, or *═C(Q.sub.411)=*′, wherein Q.sub.411 and Q.sub.412 may each independently be hydrogen, deuterium, a C.sub.1-C.sub.20 alkyl group, a C.sub.1-C.sub.20 alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group, X.sub.406 may be a single bond, O, or S, R.sub.401 and R.sub.402 may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C.sub.1-C.sub.20 alkyl group, a substituted or unsubstituted C.sub.1-C.sub.20 alkoxy group, a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkyl group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkyl group, a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkenyl group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkenyl group, a substituted or unsubstituted C.sub.6-C.sub.60 aryl group, a substituted or unsubstituted C.sub.6-C.sub.60 aryloxy group, a substituted or unsubstituted C.sub.6-C.sub.60 arylthio group, a substituted or unsubstituted C.sub.1-C.sub.60 heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(Q.sub.401)(Q.sub.402)(Q.sub.403), —N(Q.sub.401)(Q.sub.402), —B(Q.sub.401)(Q.sub.402), —C(═O)(Q.sub.401), —S(═O).sub.2(Q.sub.401), and —P(═O)(Q.sub.401)(Q.sub.402), wherein Q.sub.401 to Q.sub.403 may each independently be selected from a C.sub.1-C.sub.10 alkyl group, a C.sub.1-C.sub.10 alkoxy group, a C.sub.6-C.sub.20 aryl group, and a C.sub.1-C.sub.20 heteroaryl group, xc11 and xc12 may each independently be an integer of 0 to 10, and * and *′ in Formula 402 each indicate a binding site to M of Formula 401.
(160) In one embodiment, in Formula 402, A.sub.401 and A.sub.402 may each independently be selected from a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, an indene group, a pyrrole group, a thiophene group, a furan group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a quinoxaline group, a quinazoline group, a carbazole group, a benzimidazole group, a benzofuran group, a benzothiophene group, an isobenzothiophene group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a dibenzofuran group, and a dibenzothiophene group.
(161) In one or more embodiments, in Formula 402, i) X.sub.401 may be nitrogen, and X.sub.402 may be carbon, or ii) both X.sub.401 and X.sub.402 may be nitrogen.
(162) In one or more embodiments, in Formula 402, R.sub.401 and R.sub.402 may each independently be selected from: hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.20 alkyl group, and a C.sub.1-C.sub.20 alkoxy group; a C.sub.1-C.sub.20 alkyl group and a C.sub.1-C.sub.20 alkoxy group, each substituted with at least one selected from deuterium, —F, —

Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a phenyl group, a naphthyl group, a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbomanyl group, and a norbomenyl group; a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbomanyl group, a norbomenyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbomanyl group, a norbomenyl group a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.20 alkyl group, a C.sub.1-C.sub.20 alkoxy group, a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbomanyl group, a norbomenyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and —Si(Q.sub.401)(Q.sub.402)(Q.sub.403), —N(Q.sub.401)(Q.sub.402), —B(Q.sub.401)(Q.sub.402), —C(═O)(Q.sub.401), —S(═O).sub.2(Q.sub.401), and —P(═O)(Q.sub.401)(Q.sub.402), and Q.sub.401 to Q.sub.403 may each independently be selected from a C.sub.1-C.sub.10 alkyl group, a C.sub.1-C.sub.10 alkoxy group, a phenyl group, a biphenyl group, and a naphthyl group, but embodiments of the present disclosure are not limited thereto.

(163) In one or more embodiments, when xc1 in Formula 401 is two or more, two A.sub.401(s) in two or more L.sub.401(s) may optionally be linked via X.sub.407, which is a linking group, or two A.sub.402(s) in two or more L.sub.401(s) may optionally be linked via X.sub.408, which is a linking group (see Compounds PD1 to PD4 and PD7). X.sub.407 and X.sub.408 may each independently be a single bond, *—O—*′, *—S—*′, *—C(═O)—*′, *—N(Q.sub.413)-*′, *—C(Q.sub.413)(Q.sub.414)-*′, or *—C(Q.sub.413)═C(Q.sub.414)-*′ (wherein Q.sub.413 and Q.sub.414 may each independently be hydrogen, deuterium, a C.sub.1-C.sub.20 alkyl group, a C.sub.1-C.sub.20 alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group), but embodiments of the present disclosure are not limited thereto.

(164) L.sub.402 in Formula 401 may be a monovalent, divalent, or trivalent organic ligand. For example, L.sub.402 may be selected from halogen, diketone (for example, acetylacetonate), carboxylic acid (for example, picolinate), —C(═O), isonitrile, —CN, and phosphorus (for example, phosphine, or phosphite), but embodiments of the present disclosure are not limited thereto.

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

(166) ##STR00051## ##STR00052## ##STR00053## ##STR00054## ##STR00055##

(167) The fluorescent dopant may include an arylamine compound or a styrylamine compound.

(168) The fluorescent dopant may include a compound represented by Formula 501 below.

(169) ##STR00056##

(170) In Formula 501, Ar.sub.501 may be a substituted or unsubstituted C.sub.5-C.sub.60 carbocyclic group or a substituted or unsubstituted C.sub.1-C.sub.60 heterocyclic group, L.sub.501 to L.sub.503 may each independently be selected from a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkylene group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkylene group, a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkenylene group, a substituted or

unsubstituted C.sub.1-C.sub.10 heterocycloalkenylene group, a substituted or unsubstituted C.sub.6-C.sub.60 arylene group, a substituted or unsubstituted C.sub.1-C.sub.60 heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group, xd1 to xd3 may each independently be an integer of 0 to 3, R.sub.501 and R.sub.502 may each independently be selected from a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkyl group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkyl group, a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkenyl group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkenyl group, a substituted or unsubstituted C.sub.6-C.sub.60 aryl group, a substituted or unsubstituted C.sub.6-C.sub.60 aryloxy group, a substituted or unsubstituted C.sub.6-C.sub.60 arylthio group, a substituted or unsubstituted C.sub.1-C.sub.60 heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, and xd4 may be an integer of 1 to 6.

(171) In one embodiment, in Formula 501, Ar.sub.501 may be selected from: a naphthalene group, a heptalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, and an indenophenanthrene group; and a naphthalene group, a heptalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, and an indenophenanthrene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.20 alkyl group, a C.sub.1-C.sub.20 alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

(172) In one or more embodiments, in Formula 501, L.sub.501 to L.sub.503 may each independently be selected from: a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, and a pyridinylene group; and a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, and a pyridinylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.20 alkyl group, a C.sub.1-C.sub.20 alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a

hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group.
(173) In one or more embodiments, in Formula 501, R.sub.501 and R.sub.502 may each independently be selected from: a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group; and a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.20 alkyl group, a C.sub.1-C.sub.20 alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, and —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), and Q.sub.31 to Q.sub.33 may each independently be selected from a C.sub.1-C.sub.10 alkyl group, a C.sub.1-C.sub.10 alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.
(174) In one or more embodiments, xd4 in Formula 501 may be 2, but embodiments of the present disclosure are not limited thereto.
(175) For example, the fluorescent dopant may include at least one selected from Compounds FD1 to FD22:
(176) ##STR00057## ##STR00058## ##STR00059## ##STR00060## ##STR00061## ##STR00062##
(177) In one or more embodiments, the fluorescent dopant may include at least one selected from the following compounds, but embodiments of the present disclosure are not limited thereto.
(178) ##STR00063##
(179) The electron transport region may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.
(180) The electron transport region may include at least one selected from a buffer layer, a hole blocking layer, an electron control layer, an electron transport layer, and an electron injection layer, but embodiments of the present disclosure are not limited thereto.
(181) For example, the electron transport region may have an electron transport layer/electron injection layer structure, a hole blocking layer/electron transport layer/electron injection layer

structure, an electron control layer/electron transport layer/electron injection layer structure, or a buffer layer/electron transport layer/electron injection layer structure, wherein for each structure, constituting layers are sequentially stacked from an emission layer. However, embodiments of the structure of the electron transport region are not limited thereto.

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

(183) The "π electron-depleted nitrogen-containing ring" indicates a C.sub.1-C.sub.60 heterocyclic group having at least one *—N═*′ moiety as a ring-forming moiety.

(184) For example, the "π electron-depleted nitrogen-containing ring" may be i) a 5-membered to 7-membered heteromonocyclic group having at least one *—N═*′ moiety, ii) a heteropolycyclic group in which two or more 5-membered to 7-membered heteromonocyclic groups each having at least one *—N═*′ moiety are condensed with each other, or iii) a heteropolycyclic group in which at least one of 5-membered to 7-membered heteromonocyclic groups, each having at least one *—N═*′ moiety, is condensed with at least one C.sub.5-C.sub.60 carbocyclic group.

(185) Examples of the π electron-depleted nitrogen-containing ring include an imidazole, a pyrazole, a thiazole, an isothiazole, an oxazole, an isoxazole, a pyridine, a pyrazine, a pyrimidine, a pyridazine, an indazole, a purine, a quinoline, an isoquinoline, a benzoquinoline, a phthalazine, a naphthyridine, a quinoxaline, a quinazoline, a cinnoline, a phenanthridine, an acridine, a phenanthroline, a phenazine, a benzimidazole, an isobenzothiazole, a benzoxazole, an isobenzoxazole, a triazole, a tetrazole, an oxadiazole, a triazine, thiadiazol, an imidazopyridine, an imidazopyrimidine, and an azacarbazole, but are not limited thereto.

(186) For example, the electron transport region may include a compound represented by Formula 601:

[Ar.sub.601].sub.xe11-[(L.sub.601).sub.xe1-R.sub.601].sub.xe21. <Formula 601>

(187) In Formula 601, Ar.sub.601 may be a substituted or unsubstituted C.sub.5-C.sub.60 carbocyclic group or a substituted or unsubstituted C.sub.1-C.sub.60 heterocyclic group, xe11 may be 1, 2, or 3, L.sub.601 may be selected from a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkylene group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkylene group, a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkenylene group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkenylene group, a substituted or unsubstituted C.sub.6-C.sub.60 arylene group, a substituted or unsubstituted C.sub.1-C.sub.60 heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group, xe1 may be an integer from 0 to 5, R.sub.601 may be selected from a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkyl group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkyl group, a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkenyl group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkenyl group, a substituted or unsubstituted C.sub.6-C.sub.60 aryl group, a substituted or unsubstituted C.sub.6-C.sub.60 aryloxy group, a substituted or unsubstituted C.sub.6-C.sub.60 arylthio group, a substituted or unsubstituted C.sub.1-C.sub.60 heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(Q.sub.601)(Q.sub.602)(Q.sub.603), —C(═O)(Q.sub.601), —S(═O).sub.2(Q.sub.601), and —P(═O)(Q.sub.601)(Q.sub.602), Q.sub.601 to Q.sub.603 may each independently be a C.sub.1-C.sub.10 alkyl group, a C.sub.1-C.sub.10 alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group, and xe21 may be an integer from 1 to 5.

(188) In one embodiment, at least one of Ar.sub.601 in the number of xe11 and R.sub.601 in the number of xe21 may include the π electron-depleted nitrogen-containing ring.

(189) In one embodiment, in Formula 601, ring Ar.sub.601 may be selected from: a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a

dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, a dibenzothiophene group, a carbazole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyndazine group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, a naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, phenanthroline group, phenazine group, a benzimidazole group, an iso-benzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a thiadiazol group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group; and a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, a dibenzothiophene group, a carbazole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, a naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, phenanthroline group, phenazine group, a benzimidazole group, an iso-benzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a thiadiazol group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.20 alkyl group, a C.sub.1-C.sub.20 alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), —S(═O).sub.2(Q.sub.31) and —P(═O)(Q.sub.31)(Q.sub.32), and Q.sub.31 to Q.sub.33 may each independently be selected from a C.sub.1-C.sub.10 alkyl group, a C.sub.1-C.sub.10 alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

(190) When xe11 in Formula 601 is two or more, two or more Ar.sub.601s may be linked via a single bond.

(191) In one or more embodiments, Ar.sub.601 in Formula 601 may be an anthracene group.

(192) In one or more embodiments, a compound represented by Formula 601 may be represented by Formula 601-1:

(193) ##STR00064##

(194) In Formula 601-1, X.sub.614 may be N or C(R.sub.614), X.sub.615 may be N or C(R.sub.615), X.sub.616 may be N or C(R.sub.616), and at least one selected from X.sub.614 to X.sub.616 may be N, L.sub.611 to L.sub.613 may each independently be the same as described in connection with L.sub.601, xe611 to xe613 may each independently be the same as described in connection with xe1, R.sub.611 to R.sub.613 may each independently be the same as described in connection with R.sub.601, and R.sub.614 to R.sub.616 may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.20 alkyl group, a C.sub.1-C.sub.20 alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

(195) In one embodiment, L.sub.601 and L.sub.611 to L.sub.613 in Formulae 601 and 601-1 may each independently be selected from: a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene

group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, a pyridinylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isoxazolylene group, a thiadiazolylene group, an oxadiazolylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolylene group; and a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, a pyridinylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isoxazolylene group, a thiadiazolylene group, an oxadiazolylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.20 alkyl group, a C.sub.1-C.sub.20 alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, but embodiments of the present disclosure are not limited thereto.

(196) In one or more embodiments, xe1 and xe611 to xe613 in Formulae 601 and 601-1 may each independently be 0, 1, or 2.

(197) In one or more embodiments, R.sub.601 and R.sub.611 to R.sub.613 in Formula 601 and 601-1 may each independently be selected from: a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group; a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.20 alkyl group, a C.sub.1-C.sub.20 alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl

group, and an azacarbazolyl group; and —S(═O).sub.2(Q.sub.601) and —P(═O)(Q.sub.601)(Q.sub.602), and Q.sub.601 and Q.sub.602 are each independently the same as described above.
(198) The electron transport region may include at least one compound selected from Compounds ET1 to ET36, but embodiments of the present disclosure are not limited thereto:
(199) ##STR00065## ##STR00066## ##STR00067## ##STR00068## ##STR00069## ##STR00070## ##STR00071## ##STR00072## ##STR00073## ##STR00074## ##STR00075##
(200) In one or more embodiments, the electron transport region may include at least one compound selected from 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP), 4,7-diphenyl-1,10-phenanthroline (Bphen), Alq.sub.3, BAlq, 3-(biphenyl-4-yl)-5-(4-tert-butylphenyl)-4-phenyl-4H-1,2,4-triazole (TAZ), and NTAZ:
(201) ##STR00076##
(202) A thickness of the buffer layer, the hole blocking layer, or the electron control 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 thicknesses of the buffer layer, the hole blocking layer, and the electron control layer are within these ranges, the electron blocking layer may have excellent electron blocking characteristics or electron control characteristics without a substantial increase in driving voltage.
(203) 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 the range described above, the electron transport layer may have satisfactory electron transport characteristics without a substantial increase in driving voltage.
(204) The electron transport region (for example, the electron transport layer in the electron transport region) may further include, in addition to the materials described above, a metal-containing material.
(205) The metal-containing material may include at least one selected from alkali metal complex and alkaline earth-metal complex. The alkali metal complex may include a metal ion selected from a Li ion, a Na ion, a K ion, a Rb ion, and a Cs ion, and the alkaline earth-metal complex may include a metal ion selected from a Be ion, a Mg ion, a Ca ion, a Sr ion, and a Ba ion. A ligand coordinated with the metal ion of the alkali metal complex or the alkaline earth-metal complex may be selected from a hydroxy quinoline, a hydroxy isoquinoline, a hydroxy benzoquinoline, a hydroxy acridine, a hydroxy phenanthridine, a hydroxy phenylan oxazole, a hydroxy phenylthiazole, a hydroxy diphenylan oxadiazole, a hydroxy diphenylthiadiazol, a hydroxy phenylpyridine, a hydroxy phenylbenzimidazole, a hydroxy phenylbenzothiazole, a bipyridine, a phenanthroline, and a cyclopentadiene, but embodiments of the present disclosure are not limited thereto.
(206) For example, the metal-containing material may include a Li complex. The Li complex may include, for example, Compound ET-D1 (lithium quinolate, LiQ) or ET-D2:
(207) ##STR00077##
(208) The electron transport region may include an electron injection layer that facilitates injection of electrons from the second electrode **190**. The electron injection layer may directly contact the second electrode **190**.
(209) The electron injection layer may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.
(210) The electron injection layer may include an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare earth metal complex, or any combinations thereof.
(211) The alkali metal may be selected from Li, a Na, K, Rb, and Cs. In one embodiment, the alkali metal may be Li, a Na, or Cs. In one or more embodiments, the alkali metal may be Li or Cs, but

embodiments of the present disclosure are not limited thereto.
(212) The alkaline earth metal may be selected from Mg, Ca, Sr, and Ba.
(213) The rare earth metal may be selected from Sc, Y, Ce, Tb, Yb, and Gd.
(214) The alkali metal compound, the alkaline earth-metal compound, and the rare earth metal compound may be selected from oxides and halides (for example, fluorides, chlorides, bromides, or iodides) of the alkali metal, the alkaline earth-metal, and the rare earth metal.
(215) The alkali metal compound may be selected from alkali metal oxides, such as Li.sub.2O, Cs.sub.2O, or K.sub.2O, and alkali metal halides, such as LiF, a NaF, CsF, KF, LiI, a NaI, CsI, KI, or RbI. In one embodiment, the alkali metal compound may be selected from LiF, Li.sub.2O, a NaF, LiI, a NaI, CsI, and KI, but embodiments of the present disclosure are not limited thereto.
(216) The alkaline earth-metal compound may be selected from alkaline earth-metal oxides, such as BaO, SrO, CaO, Ba.sub.xSr.sub.1-xO (0<x<1), Ba.sub.xCa.sub.1-xO (0<x<1). In one embodiment, the alkaline earth-metal compound may be selected from BaO, SrO, and CaO, but embodiments of the present disclosure are not limited thereto.
(217) The rare earth metal compound may be selected from YbF.sub.3, ScF.sub.3, ScO.sub.3, Y.sub.2O.sub.3, Ce.sub.2O.sub.3, GdF.sub.3, and TbF.sub.3. In one embodiment, the rare earth metal compound may be selected from YbF.sub.3, ScF.sub.3, TbF.sub.3, YbI.sub.3, ScI.sub.3, and TbI.sub.3, but embodiments of the present disclosure are not limited thereto.
(218) The alkali metal complex, the alkaline earth-metal complex, and the rare earth metal complex may include an ion of alkali metal, alkaline earth-metal, and rare earth metal as described above, and a ligand coordinated with a metal ion of the alkali metal complex, the alkaline earth-metal complex, or the rare earth metal complex may be selected from hydroxy quinoline, hydroxy isoquinoline, hydroxy benzoquinoline, hydroxy acridine, hydroxy phenanthridine, hydroxy phenylan oxazole, hydroxy phenylthiazole, hydroxy diphenylan oxadiazole, hydroxy diphenyithiadiazol, hydroxy phenylpyridine, hydroxy phenylbenzimidazole, hydroxy phenylbenzothiazole, bipyridine, phenanthroline, and cyclopentadiene, but embodiments of the present disclosure are not limited thereto.
(219) The electron injection layer may consist of an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare earth metal complex, or any combinations thereof, as described above. In one or more embodiments, the electron injection layer may further include an organic material. When the electron injection layer further includes an organic material, an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare earth metal complex, or any combinations thereof may be homogeneously or non-homogeneously dispersed in a matrix including the organic material.
(220) 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 the range described above, the electron injection layer may have satisfactory electron injection characteristics without a substantial increase in driving voltage.
(221) The second electrode **190** is disposed on the organic layer **150** having such a structure. 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 metal, an alloy, an electrically conductive compound, and a combination thereof, which have a relatively low work function.
(222) The second electrode **190** may include at least one selected from lithium (Li), silver (Ag), magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), magnesium-silver (Mg—Ag), ITO, and IZO, but embodiments of the present disclosure are not limited thereto. The second electrode **190** may be a transmissive electrode, a semi-

transmissive electrode, or a reflective electrode.
(223) The first electrode **190** may have a single-layered structure, or a multi-layered structure including two or more layers.
(224) Hereinbefore, the organic light-emitting device has been described with reference to the FIGURE, but embodiments of the present disclosure are not limited thereto.
(225) Layers constituting the hole transport region, an emission layer, and layers constituting the electron transport region may be formed in a certain region by using one or more suitable methods selected from vacuum deposition, spin coating, casting, Langmuir-Blodgett (LB) deposition, ink-jet printing, laser-printing, and laser-induced thermal imaging.
(226) In one embodiment, the first organic layer is formed by performing a solution process, and the second organic layer is formed by deposition.
(227) When layers constituting the hole transport region, an emission layer, and layers constituting the electron transport region are formed by vacuum deposition, for example, the vacuum deposition may be performed at a deposition temperature of about 100° C. to about 500° C., at a pressure of about 10.sup.−8 torr to about 10.sup.−3 torr, and at a deposition rate of about 0 Å/sec to about 100 Å/sec by taking into account a material to be included in a layer to be formed, and the structure of a layer to be formed.
(228) When layers constituting the hole transport region, an emission layer, and layers constituting the electron transport region are formed by spin coating, the spin coating may be performed at a coating speed of about 2,000 rpm to about 5,000 rpm and at a heat treatment temperature of about 80° C. to 200° C. by taking into account a material to be included in a layer to be formed, and the structure of a layer to be formed.
(229) The term “C.sub.1-C.sub.60 alkyl group” as used herein refers to a linear or branched saturated aliphatic hydrocarbon monovalent group having 1 to 60 carbon atoms, and examples thereof include a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, a pentyl group, an iso-amyl group, and a hexyl group. The term “C.sub.1-C.sub.60 alkylene group” as used herein refers to a divalent group having the same structure as the C.sub.1-C.sub.60 alkyl group.
(230) The term “C.sub.2-C.sub.60 alkenyl group” as used herein refers to a hydrocarbon group having at least one carbon-carbon double bond in the middle or at the terminus of the C.sub.2-C.sub.60 alkyl group, and examples thereof include an ethenyl group, a propenyl group, and a butenyl group. The term “C.sub.2-C.sub.60 alkenylene group” as used herein refers to a divalent group having the same structure as the C.sub.2-C.sub.60 alkenyl group.
(231) The term ‘C.sub.2-C.sub.60 alkynyl group’ as used herein refers to a hydrocarbon group having at least one carbon-carbon triple bond in the middle or at the terminus of the C.sub.2-C.sub.60 alkyl group, and examples thereof include an ethynyl group, and a propynyl group. The term “C.sub.2-C.sub.60 alkynylene group” as used herein refers to a divalent group having the same structure as the C.sub.2-C.sub.60 alkynyl group.
(232) The term “C.sub.1-C.sub.60 alkoxy group” as used herein refers to a monovalent group represented by —OA.sub.101 (wherein A.sub.101 is the C.sub.1-C.sub.60 alkyl group), and examples thereof include a methoxy group, an ethoxy group, and an isopropyloxy group.
(233) The term “C.sub.3-C.sub.10 cycloalkyl group” as used herein refers to a monovalent saturated hydrocarbon monocyclic group having 3 to 10 carbon atoms, and examples thereof include a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. The term “C.sub.3-C.sub.10 cycloalkylene group” as used herein refers to a divalent group having the same structure as the C.sub.3-C.sub.10 cycloalkyl group.
(234) The term “C.sub.1-C.sub.10 heterocycloalkyl group” as used herein refers to a monovalent monocyclic group having at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom and 1 to 10 carbon atoms, and examples thereof include a 1,2,3,4-oxatriazolidinyl group, a tetrahydrofuranyl group, and a tetrahydrothiophenyl group. The term “C.sub.1-C.sub.10

heterocycloalkylene group" used herein refers to a divalent group having the same structure as the C.sub.1-C.sub.10 heterocycloalkyl group.
(235) A C.sub.3-C.sub.10 cycloalkenyl group used herein refers to a monovalent monocyclic group that has 3 to 10 carbon atoms and at least one carbon-carbon double bond in the ring thereof and no aromaticity, and examples thereof include a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. The term "C.sub.3-C.sub.10 cycloalkenylene group," used herein, refers to a divalent group having the same structure as the C.sub.3-C.sub.10 cycloalkenyl group.
(236) The term "C.sub.1-C.sub.10 heterocycloalkenyl group" as used herein refers to a monovalent monocyclic group that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, 1 to 10 carbon atoms, and at least one carbon-carbon double bond in its ring. Non-limiting examples of the C.sub.1-C.sub.10 heterocycloalkenyl group include a 4,5-dihydro-1,2,3,4-oxatriazolyl group, a 2,3-dihydrofuranyl group, and a 2,3-dihydrothiophenyl group. The term "C.sub.1-C.sub.10 heterocycloalkenylene group," used herein, refers to a divalent group having the same structure as the C.sub.1-C.sub.10 heterocycloalkenyl group.
(237) The term "C.sub.6-C.sub.60 aryl group" as used herein refers to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms, and a C.sub.6-C.sub.60 arylene group used herein refers to a divalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms. Examples of the C.sub.6-C.sub.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.sub.6-C.sub.60 aryl group and the C.sub.6-C.sub.60 arylene group each include two or more rings, the rings may be fused to each other.
(238) The term "C.sub.1-C.sub.60 heteroaryl group" as used herein refers to a monovalent group having a carbocyclic aromatic system that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, in addition to 1 to 1 carbon atoms. The term "C.sub.1-C.sub.60 heteroarylene group" as used herein refers to a divalent group having a carbocyclic aromatic system that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, in addition to 1 to 60 carbon atoms. Examples of the C.sub.1-C.sub.60 heteroaryl group are a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, and an isoquinolinyl group. When the C.sub.1-C.sub.60 heteroaryl group and the C.sub.1-C.sub.60 heteroarylene group each include two or more rings, the rings may be fused to each other.
(239) The term "C.sub.6-C.sub.60 aryloxy group," used herein, indicates —OA.sub.102 (wherein A.sub.102 is the C.sub.6-C.sub.60 aryl group), and a C.sub.6-C.sub.60 arylthio group indicates —SA.sub.103 (wherein A.sub.103 is the C.sub.6-C.sub.60 aryl group).
(240) The term "monovalent non-aromatic condensed polycyclic group" as used herein refers to a monovalent group (for example, having 8 to 60 carbon atoms) having two or more rings condensed with each other, only carbon atoms as ring-forming atoms, and no aromaticity in its entire molecular structure. A detailed example of the monovalent non-aromatic condensed polycyclic group is a fluorenyl group. The term "divalent non-aromatic condensed polycyclic group," used herein, refers to a divalent group having the same structure as the monovalent non-aromatic condensed polycyclic group.
(241) The term "monovalent non-aromatic condensed heteropolycyclic group" as used herein refers to a monovalent group (for example, having 1 to 60 carbon atoms) having two or more rings condensed to each other, at least one heteroatom selected from N, O, Si, P, and S, other than carbon atoms, as a ring-forming atom, and no aromaticity in its entire molecular structure. An example of the monovalent non-aromatic condensed heteropolycyclic group is a carbazolyl group. The term "divalent non-aromatic condensed heteropolycyclic group" as used herein refers to a divalent group having the same structure as the monovalent non-aromatic condensed heteropolycyclic group.
(242) The term "C.sub.5-C.sub.60 carbocyclic group" as used herein refers to a monocyclic or polycyclic group having 5 to 60 carbon atoms in which a ring-forming atom is a carbon atom only.

The C.sub.5-C.sub.60 carbocyclic group may be an aromatic carbocyclic group or a non-aromatic carbocyclic group. The C.sub.5-C.sub.60 carbocyclic group may be a ring such as a benzene, a monovalent group such as a phenyl group, or a divalent group such as a phenylene group. In one or more embodiments, depending on the number of substituents connected to the C.sub.5-C.sub.60 carbocyclic group, the C.sub.5-C.sub.60 carbocyclic group may be a trivalent group or a quadrivalent group.

(243) The term "C.sub.1-C.sub.60 heterocyclic group" as used herein refers to a group having the same structure as the C.sub.5-C.sub.60 carbocyclic group, except that as a ring-forming atom, at least one heteroatom selected from N, O, Si, P, and S is used in addition to carbon (the number of carbon atoms may be in a range of 1 to 60).

(244) At least one substituent of the substituted C.sub.5-C.sub.60 carbocyclic group, the substituted C.sub.1-C.sub.60 heterocyclic group, the substituted C.sub.3-C.sub.10 cycloalkylene group, the substituted C.sub.1-C.sub.10 heterocycloalkylene group, the substituted C.sub.3-C.sub.10 cycloalkenylene group, the substituted C.sub.1-C.sub.10 heterocycloalkenylene group, the substituted C.sub.6-C.sub.60 arylene group, the substituted C.sub.1-C.sub.60 heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, the substituted divalent non-aromatic condensed heteropolycyclic group, the substituted C.sub.1-C.sub.60 alkyl group, the substituted C.sub.2-C.sub.60 alkenyl group, the substituted C.sub.2-C.sub.60 alkynyl group, the substituted C.sub.1-C.sub.60 alkoxy group, the substituted C.sub.3-C.sub.10 cycloalkyl group, the substituted C.sub.1-C.sub.10 heterocycloalkyl group, the substituted C.sub.3-C.sub.10 cycloalkenyl group, the substituted C.sub.1-C.sub.10 heterocycloalkenyl group, the substituted C.sub.6-C.sub.60 aryl group, the substituted C.sub.6-C.sub.60 aryloxy group, the substituted C.sub.6-C.sub.60 arylthio group, the substituted C.sub.1-C.sub.60 heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from: deuterium (—D), —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.60 alkyl group, a C.sub.2-C.sub.60 alkenyl group, a C.sub.2-C.sub.60 alkynyl group, and a C.sub.1-C.sub.60 alkoxy group; a C.sub.1-C.sub.60 alkyl group, a C.sub.2-C.sub.60 alkenyl group, a C.sub.2-C.sub.60 alkynyl group, and a C.sub.1-C.sub.60 alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.1-C.sub.10 heterocycloalkyl group, a C.sub.3-C.sub.10 cycloalkenyl group, a C.sub.1-C.sub.10 heterocycloalkenyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.6-C.sub.60 aryloxy group, a C.sub.6-C.sub.60 arylthio group, a C.sub.1-C.sub.60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —Si(Q.sub.11)(Q.sub.12)(Q.sub.13), —N(Q.sub.11)(Q.sub.12), —B(Q.sub.11)(Q.sub.12), —C(═O)(Q.sub.11), —S(═O).sub.2(Q.sub.11), and —P(═O)(Q.sub.11)(Q.sub.12); a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.1-C.sub.10 heterocycloalkyl group, a C.sub.3-C.sub.10 cycloalkenyl group, a C.sub.1-C.sub.10 heterocycloalkenyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.6-C.sub.60 aryloxy group, a C.sub.6-C.sub.60 arylthio group, a C.sub.1-C.sub.60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group; a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.1-C.sub.10 heterocycloalkyl group, a C.sub.3-C.sub.10 cycloalkenyl group, a C.sub.1-C.sub.10 heterocycloalkenyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.6-C.sub.60 aryloxy group, a C.sub.6-C.sub.60 arylthio group, a C.sub.1-C.sub.60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.60 alkyl group, a C.sub.2-C.sub.60 alkenyl group, a C.sub.2-C.sub.60 alkynyl group, a C.sub.1-C.sub.60 alkoxy group, a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.1-C.sub.10

heterocycloalkyl group, a C.sub.3-C.sub.10 cycloalkenyl group, a C.sub.1-C.sub.10 heterocycloalkenyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.6-C.sub.60 aryloxy group, a C.sub.6-C.sub.60 arylthio group, a C.sub.1-C.sub.60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —Si(Q.sub.21)(Q.sub.22)(Q.sub.23), —N(Q.sub.21)(Q.sub.22), —B(Q.sub.21)(Q.sub.22), —C(═O)(Q.sub.21), —S(═O).sub.2(Q.sub.21), and —P(═O)(Q.sub.21)(Q.sub.22); and —Si(Q.sub.31)(Q.sub.3)(Q.sub.33), —N(Q.sub.31)(Q.sub.32), —B(Q.sub.31)(Q.sub.32), —C(═O)(Q.sub.31), —S(═O).sub.2(Q.sub.31), and —P(═O)(Q.sub.31)(Q.sub.32).

(245) In one embodiment, at least one substituent of the substituted C.sub.5-C.sub.60 carbocyclic group, the substituted C.sub.1-C.sub.60 heterocyclic group, the substituted C.sub.1-C.sub.60 alkyl group, the substituted C.sub.2-C.sub.60 alkenyl group, the substituted C.sub.2-C.sub.60 alkynyl group, the substituted C.sub.1-C.sub.60 alkoxy group, the substituted C.sub.3-C.sub.10 cycloalkyl group, the substituted C.sub.1-C.sub.10 heterocycloalkyl group, the substituted C.sub.3-C.sub.10 cycloalkenyl group, the substituted C.sub.1-C.sub.10 heterocycloalkenyl group, the substituted C.sub.6-C.sub.60 aryl group, the substituted C.sub.6-C.sub.60 aryloxy group, the substituted C.sub.6-C.sub.60 arylthio group, the substituted C.sub.1-C.sub.60 heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.60 alkyl group, a C.sub.2-C.sub.60 alkenyl group, a C.sub.2-C.sub.60 alkynyl group, a C.sub.1-C.sub.60 alkoxy group, a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.1-C.sub.10 heterocycloalkyl group, a C.sub.3-C.sub.10 cycloalkenyl group, a C.sub.1-C.sub.10 heterocycloalkenyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.6-C.sub.60 aryloxy group, a C.sub.6-C.sub.60 arylthio group, a C.sub.1-C.sub.60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

(246) Q.sub.11 to Q.sub.13, Q.sub.21 to Q.sub.23, and Q.sub.31 to Q.sub.33 may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.60 alkyl group, a C.sub.2-C.sub.60 alkenyl group, a C.sub.2-C.sub.60 alkynyl group, a C.sub.1-C.sub.60 alkoxy group, a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.1-C.sub.10 heterocycloalkyl group, a C.sub.3-C.sub.10 cycloalkenyl group, a C.sub.1-C.sub.10 heterocycloalkenyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.1-C.sub.60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

(247) In one embodiment, Q.sub.31 to Q.sub.33 may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.60 alkyl group, a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.1-C.sub.10 heterocycloalkyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.6-C.sub.60 aryl group substituted with a C.sub.1-C.sub.60 alkyl group, a C.sub.1-C.sub.60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

(248) In one embodiment, Q.sub.31 to Q.sub.33 may each independently be selected from hydrogen, deuterium, a C.sub.1-C.sub.60 alkyl group, a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.6-C.sub.60 aryl group substituted with a C.sub.1-C.sub.60 alkyl group, and a C.sub.1-C.sub.60 heteroaryl group.

(249) The term “Ph” as used herein represents a phenyl group, the term “Me” as used herein represents a methyl group, the term “Et” as used herein represents an ethyl group, the term “ter-Bu” or “Bu.sup.t,” as used herein, represents a tert-butyl group, the term “OMe” as used herein represents a methoxy group, and the term “TMS” as used herein represents a trimethylsilyl group.

(250) The term “biphenyl group” used herein refers to a “phenyl group substituted with a phenyl group. The “biphenyl group” is a “substituted phenyl group” having a “C.sub.6-C.sub.60 aryl group” as a substituent.
(251) The term “terphenyl group” used herein refers to a “phenyl group substituted with a biphenyl group. The “terphenyl group” is “a substituted phenyl group” having a “C.sub.6-C.sub.60 aryl group substituted with a C.sub.6-C.sub.60 aryl group” as a substituent.
(252) * and *′ used herein, unless defined otherwise, each refer to a binding site to a neighboring atom in a corresponding formula.
(253) Hereinafter, a compound according to embodiments and an organic light-emitting device according to embodiments will be described in detail with reference to Examples. The expression “B was used instead of A” used in describing Examples means that an identical number of molar equivalents of A was used in place of molar equivalents of B.
(254) Compounds used in Examples may be synthesized by using methods known in the art. For example, the compound represented by Formula 1 may be synthesized by referring to the description provided in Journal of Chemical Education (2013), 90(6), pp. 786-789 or Appl. Phys. Lett. 91, 183504 (2007). As another example, the compound represented by Formula 2 may be synthesized by referring to Korean Patent Registration No. 10-1109561.

EXAMPLES

Example 1

(255) An ITO glass substrate (50 mm×50 mm, 15 Ω/cm.sup.2), which was a substrate obtained from an OLED glass (manufactured by Samsung Corning Co., Ltd.), was sonicated with distilled water and isopropanol and then cleaned by exposure to ultraviolet rays and ozone for 30 minutes. PEDOT:PSS was spin-coated on the cleaned ITO glass substrate with a transparent electrode line to form a film having a thickness of 60 nm, and a baking process was performed thereon at a temperature of 200° C. for 30 minutes to form a hole injection layer. TFB was spin-coated on the hole injection layer to form a film having a thickness of 20 nm, and a baking process was performed thereon at a temperature of 130° C. for 10 minutes to form a hole transport layer. Then, an ink including Compound 1 (host), Compound 105 (dopant, 3 wt %), methyl benzoate (solvent) was spin-coated on the hole transport layer to form a film having a thickness of 30 nm, and a baking process was performed thereon at a temperature of 130° C. for 10 minutes to form an emission layer. The ITO glass substrate was mounted on a substrate holder of a vacuum deposition apparatus, and Compound 301 was deposited on the emission layer to form an electron transport layer having a thickness of 20 nm. 8-hydroxyquinolinolato-lithium (LiQ) was deposited on the electron transport layer to form an electron injection layer having a thickness of 1 nm, and Al was deposited on the electron injection layer to form a cathode having a thickness of 100 nm, thereby completing the manufacture of an organic light-emitting device. The deposition apparatus was Suicel plus 200 (manufactured by Sunic System Co., Ltd).
(256) ##STR00078## ##STR00079##

Examples 2 to 10 and Comparative Examples 1 to 3

(257) Organic light-emitting devices were manufactured in the same manner as in Example 1, except that Compounds shown in Table 1 were used as a host material and a dopant material.

Comparative Examples 4 and 5

(258) Organic light-emitting devices were manufactured in the same manner as in Example 1, except that Compounds shown in Table 1 were used as a solvent.
(259) TABLE-US-00001 TABLE 1 Host Dopant Solvent Example 1 Compound 1 Compound 105 Methyl benzoate Example 2 Compound 2 Compound 105 Methyl benzoate Example 3 Compound 3 Compound 105 Methyl benzoate Example 4 Compound 4 Compound 105 Methyl benzoate Example 5 Compound 1 Compound 106 Methyl benzoate Example 6 Compound 2 Compound 106 Methyl benzoate Example 7 Compound 3 Compound 106 Methyl benzoate Example 8 Compound 4 Compound 106 Methyl benzoate Example 9 Compound 45 Compound 105 Methyl benzoate

Example 10 Compound 45 Compound 106 Methyl benzoate Comparative Compound 302 Compound 303 Methyl benzoate Example 1 Comparative Compound 1 Compound 303 Methyl benzoate Example 2 Comparative Compound 302 Compound 105 Methyl benzoate Example 3 Comparative Compound 1 Compound 105 Toluene Example 4 Comparative Compound 1 Compound 105 Cyclohexanone Example 5

Evaluation Example

(260) The driving voltage, efficiency, and color purity of the organic light-emitting devices manufactured according to Examples 1 to 10 and Comparative Examples 1 to 5 were measured by using the following methods. Results thereof are shown in Table 2. Color coordinates: A current-voltage meter (Keithley SMU 236) supplied power and a luminance meter PR650 was used to measure color coordinates. Luminance: A current-voltage meter (Keithley SMU 236) supplied power and a luminance meter PR650 was used to measure luminance. Efficiency: A current-voltage meter (Keithley SMU 236) supplied power and a luminance meter PR650 was used to measure efficiency.

(261) Lifespan (T95) indicates an amount of time (hr) that lapsed when luminance was 95% of initial luminance (100%) (@10 mA/cm.sup.2).

(262) TABLE-US-00002 TABLE 2 Driving Lifespan voltage Efficiency Color coordinates (T95) [V] [cd/A] CIEx CIEy [hr] Example 1 4.4 6.0 0.15 0.16 120 Example 2 4.4 5.8 0.15 0.16 150 Example 3 4.3 6.0 0.15 0.16 130 Example 4 4.5 5.9 0.15 0.16 110 Example 5 4.4 6.1 0.15 0.16 120 Example 6 4.3 6.2 0.15 0.16 125 Example 7 4.4 5.9 0.15 0.16 130 Example 8 4.5 6.0 0.15 0.16 140 Example 9 4.4 5.6 0.15 0.16 100 Example 10 4.4 5.5 0.15 0.16 90 Comparative 4.4 4.8 0.15 0.16 20 Example 1 Comparative 4.3 5.2 0.15 0.16 30 Example 2 Comparative 4.5 5.0 0.15 0.16 30 Example 3 Comparative 5.2 4.8 0.15 0.18 20 Example 4 Comparative 5.0 4.5 0.15 0.18 20 Example 5 @10 mA/cm.sup.2

(263) Referring to Table 1, it is confirmed that the organic light-emitting device using the compound represented by Formula 1, in which a reactive position is substituted, and the polar solvent has excellent driving voltage, efficiency, and lifespan characteristics, as compared with those of the organic light-emitting devices of the Comparative Examples.

(264) An organic light-emitting device manufactured by using the ink composition may have a low driving voltage, high efficiency, high luminance, and a long lifespan.

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

(266) While one or more embodiments 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 spirit and scope as defined by the following claims.

Claims

1. An ink composition comprising: a compound represented by Formula 1, an amine-based compound represented by Formula 2, and a polar solvent: ##STR00080## ##STR00081## wherein, in Formula 1, *-(L.sub.1).sub.a1-(R.sub.1).sub.b1 is a group represented by Formula 1-2 and *-(L.sub.2).sub.a2-(R.sub.2).sub.b2 is a group represented by Formula 1-3: ##STR00082## wherein in Formulae 1-2 and 1-3, * indicates a binding site to a neighboring atom, R.sub.3, R.sub.6, R.sub.7, and R.sub.10 are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), a substituted or unsubstituted C.sub.1-C.sub.60 alkyl group, a substituted or unsubstituted C.sub.2-C.sub.60 alkenyl group, a substituted or unsubstituted C.sub.2-C.sub.60 alkynyl group, a substituted or unsubstituted C.sub.1-C.sub.60 alkoxy group, a substituted or unsubstituted C.sub.3-

C.sub.10 cycloalkyl group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkyl group, a substituted or unsubstituted C.sub.3-C.sub.10 cycloalkenyl group, a substituted or unsubstituted C.sub.1-C.sub.10 heterocycloalkenyl group, a substituted or unsubstituted C.sub.6-C.sub.60 aryl group, a substituted or unsubstituted C.sub.6-C.sub.60 aryloxy group, a substituted or unsubstituted C.sub.6-C.sub.60 arylthio group, a substituted or unsubstituted C.sub.1-C.sub.60 heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, R.sub.4 and R.sub.8 are each hydrogen, R.sub.5 and R.sub.9 are each independently selected from deuterium and a C.sub.1-C.sub.10 alkyl group, at least one substituent of the substituted C.sub.1-C.sub.60 alkyl group, the substituted C.sub.2-C.sub.60 alkenyl group, the substituted C.sub.2-C.sub.60 alkynyl group, the substituted C.sub.1-C.sub.60 alkoxy group, the substituted C.sub.3-C.sub.10 cycloalkyl group, the substituted C.sub.1-C.sub.10 heterocycloalkyl group, the substituted C.sub.3-C.sub.10 cycloalkenyl group, the substituted C.sub.1-C.sub.10 heterocycloalkenyl group, the substituted C.sub.6-C.sub.60 aryl group, the substituted C.sub.6-C.sub.60 aryloxy group, the substituted C.sub.6-C.sub.60 arylthio group, the substituted C.sub.1-C.sub.60 heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group is selected from: deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.60 alkyl group, a C.sub.2-C.sub.60 alkenyl group, a C.sub.2-C.sub.60 alkynyl group, and a C.sub.1-C.sub.60 alkoxy group; a C.sub.1-C.sub.60 alkyl group, a C.sub.2-C.sub.60 alkenyl group, a C.sub.2-C.sub.60 alkynyl group, and a C.sub.1-C.sub.60 alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.1-C.sub.10 heterocycloalkyl group, a C.sub.3-C.sub.10 cycloalkenyl group, a C.sub.1-C.sub.10 heterocycloalkenyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.6-C.sub.60 aryloxy group, a C.sub.6-C.sub.60 arylthio group, a C.sub.1-C.sub.60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group; a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.1-C.sub.10 heterocycloalkyl group, a C.sub.3-C.sub.10 cycloalkenyl group, a C.sub.1-C.sub.10 heterocycloalkenyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.6-C.sub.60 aryloxy group, a C.sub.6-C.sub.60 arylthio group, a C.sub.1-C.sub.60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group; a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.1-C.sub.10 heterocycloalkyl group, a C.sub.3-C.sub.10 cycloalkenyl group, a C.sub.1-C.sub.10 heterocycloalkenyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.6-C.sub.60 aryloxy group, a C.sub.6-C.sub.60 arylthio group, a C.sub.1-C.sub.60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.60 alkyl group, a C.sub.2-C.sub.60 alkenyl group, a C.sub.2-C.sub.60 alkynyl group, a C.sub.1-C.sub.60 alkoxy group, a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.1-C.sub.10 heterocycloalkyl group, a C.sub.3-C.sub.10 cycloalkenyl group, a C.sub.1-C.sub.10 heterocycloalkenyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.6-C.sub.60 aryloxy group, a C.sub.6-C.sub.60 arylthio group, a C.sub.1-C.sub.60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group; and —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), —N(Q.sub.31)(Q.sub.32), —B(Q.sub.31)(Q.sub.32), —C(═O)(Q.sub.31), —S(═O).sub.2(Q.sub.31), and —P(═O)(Q.sub.31)(Q.sub.32), and Q.sub.31 to Q.sub.33 are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.60

alkyl group, a C.sub.2-C.sub.60 alkenyl group, a C.sub.2-C.sub.60 alkynyl group, a C.sub.1-C.sub.60 alkoxy group, a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.1-C.sub.10 heterocycloalkyl group, a C.sub.3-C.sub.10 cycloalkenyl group, a C.sub.1-C.sub.10 heterocycloalkenyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.6-C.sub.60 aryl group substituted with a C.sub.1-C.sub.60 alkyl group, a C.sub.1-C.sub.60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group; and wherein, in Formula 2, L.sub.11 and L.sub.12 are each independently a substituted or unsubstituted C.sub.5-C.sub.60 carbocyclic group or a substituted or unsubstituted C.sub.1-C.sub.60 heterocyclic group, R.sub.15, R.sub.16, R.sub.18 to R.sub.20, and R.sub.22 are each independently hydrogen, R.sub.17 and R.sub.21 are each independently deuterium, a11 and a12 are each independently an integer from 0 to 5, at least one substituent of the substituted C.sub.5-C.sub.60 carbocyclic group and the substituted C.sub.1-C.sub.60 heterocyclic group is selected from: deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.60 alkyl group, a C.sub.2-C.sub.60 alkenyl group, a C.sub.2-C.sub.60 alkynyl group, and a C.sub.1-C.sub.60 alkoxy group; a C.sub.1-C.sub.60 alkyl group, a C.sub.2-C.sub.60 alkenyl group, a C.sub.2-C.sub.60 alkynyl group, and a C.sub.1-C.sub.60 alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.1-C.sub.10 heterocycloalkyl group, a C.sub.3-C.sub.10 cycloalkenyl group, a C.sub.1-C.sub.10 heterocycloalkenyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.6-C.sub.60 aryloxy group, C.sub.6-C.sub.60 arylthio group, C.sub.1-C.sub.60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group; a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.1-C.sub.10 heterocycloalkyl group, a C.sub.3-C.sub.10 cycloalkenyl group, a C.sub.1-C.sub.10 heterocycloalkenyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.6-C.sub.60 aryloxy group, a C.sub.6-C.sub.60 arylthio group, a C.sub.1-C.sub.60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group; a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.1-C.sub.10 heterocycloalkyl group, a C.sub.3-C.sub.10 cycloalkenyl group, a C.sub.1-C.sub.10 heterocycloalkenyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.6-C.sub.60 aryloxy group, a C.sub.6-C.sub.60 arylthio group, a C.sub.1-C.sub.60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.60 alkyl group, a C.sub.2-C.sub.60 alkenyl group, a C.sub.2-C.sub.60 alkynyl group, a C.sub.1-C.sub.60 alkoxy group, a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.1-C.sub.10 heterocycloalkyl group, a C.sub.3-C.sub.10 cycloalkenyl group, a C.sub.1-C.sub.10 heterocycloalkenyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.6-C.sub.60 aryloxy group, a C.sub.6-C.sub.60 arylthio group, a C.sub.1-C.sub.60 heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group; and —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), —N(Q.sub.31)(Q.sub.32), —B(Q.sub.31)(Q.sub.32), —C(═O)(Q.sub.31), —S(═O).sub.2(Q.sub.31), and —P(═O)(Q.sub.31)(Q.sub.32), and Q.sub.31 to Q.sub.33 are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C.sub.1-C.sub.60 alkyl group, a C.sub.2-C.sub.60 alkenyl group, a C.sub.2-C.sub.60 alkynyl group, a C.sub.1-C.sub.60 alkoxy group, a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.1-C.sub.10 heterocycloalkyl group, a C.sub.3-C.sub.10 cycloalkenyl group, a C.sub.1-C.sub.10 heterocycloalkenyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.6-C.sub.60 aryl group substituted with a C.sub.1-C.sub.60 alkyl group, a C.sub.1-C.sub.60 heteroaryl group, a monovalent non-aromatic condensed

polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, and *-(L.sub.21).sub.a21-(R.sub.11).sub.b11, *-(L.sub.22).sub.a22-(R.sub.12).sub.b12, *-(L.sub.23).sub.a23-(R.sub.13).sub.b13, and *-(L.sub.24).sub.a24-(R.sub.14).sub.b14 are each independently selected from groups represented by Formulae 2-1 to 2-4: ##STR00083## wherein in Formulae 2-1 to 2-4, * indicates a binding site to a neighboring atom, and wherein the polar solvent is a C.sub.1-C.sub.10 alkyl benzoate.

2. The ink composition of claim 1, wherein R.sub.3, R.sub.6, R.sub.7, and R.sub.10 are each independently selected from: hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a C.sub.1-C.sub.20 alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-fluorene-benzofluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a biphenylyl group; and —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, and a hexyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, —Si(Q.sub.31)(Q.sub.32)(Q.sub.33), a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a spiro-fluorene-benzofluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyridinyl group, a pyrimidyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, and a biphenylyl group, and Q.sub.31 to Q.sub.33 are each independently selected from hydrogen, deuterium, a C.sub.1-C.sub.60 alkyl group, a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.6-C.sub.60 aryl group substituted with a C.sub.1-C.sub.60 alkyl group, and a C.sub.1-C.sub.60 heteroaryl group.

3. The ink composition of claim 1, wherein R.sub.5 and R.sub.9 are each independently selected from deuterium, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, and a hexyl group.

4. The ink composition of claim 1, wherein L.sub.11 and L.sub.12 are each independently selected from: a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a naphthofluorene group, a carbazole group, a dibenzofuran group, a benzonaphthofuran group, a dibenzothiophene group, a benzocarbazole group, and a dibenzocarbazole group; and a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a naphthofluorene group, a carbazole group, a dibenzofuran group, a benzonaphthofuran group, a dibenzothiophene group, a benzocarbazole group, and a dibenzocarbazole group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a ter-butyl group, a pentyl group, an iso-amyl group, a hexyl group, a

C.sub.1-C.sub.20 alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a carbazolyl group, a dibenzofuranyl group, a benzonaphthofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group.

5. The ink composition of claim 1, wherein Q.sub.31 to Q.sub.33 are each independently selected from hydrogen, deuterium, a C.sub.1-C.sub.60 alkyl group, a C.sub.3-C.sub.10 cycloalkyl group, a C.sub.6-C.sub.60 aryl group, a C.sub.6-C.sub.60 aryl group substituted with a C.sub.1-C.sub.60 alkyl group, and a C.sub.1-C.sub.60 heteroaryl group.

6. The ink composition of claim 1, wherein the polar solvent has a relative polarity of 0.2 to 0.4.

7. The ink composition of claim 1, wherein a solubility of the compound represented by Formula 1 in the polar solvent is in a range of 1% to 10%, and a solubility of the compound represented by Formula 2 in the polar solvent is in a range of 0.01% to 2%.

8. The ink composition of claim 1, wherein the ink composition comprises: 1 part by weight to 10 parts by weight of the compound represented by Formula 1; 0.01 parts by weight to 2 parts by weight of the compound represented by Formula 2; and 90 parts by weight to 99 parts by weight of the polar solvent.

9. An organic light-emitting device comprising: a first electrode; a second electrode facing the first electrode; and an organic layer that is disposed between the first electrode and the second electrode and comprises an emission layer, wherein the organic layer is formed by using the ink composition of claim 1.

10. The organic light-emitting device of claim 9, wherein the emission layer comprises a host and a dopant, the host comprises a compound represented by Formula 1, the dopant comprises a component represented by Formula 2.

11. The organic light-emitting device of claim 9, wherein the emission layer comprises a blue emission layer that emits blue fluorescence.

12. A method of manufacturing an organic light-emitting device, the method comprising: forming an organic layer between the first electrode and the second electrode and comprising an emission layer, wherein the forming of the organic layer comprises performing a solution process using the ink composition of claim 1.

13. The method of claim 12, wherein the solution process is spin coating, slot coating, dip coating, bar coating, roll coating, gravure coating, micro gravure coating, wire coating, spray coating, ink-jet coating, nozzle coating, screen printing, flexo printing, offset printing, or casting.

14. The method of claim 12, wherein the forming of the organic layer further comprises evaporating the polar solvent.

15. The method of claim 14, wherein the evaporating of the polar solvent is performed at a temperature of 130° C. to be 160° C.