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KIM et al.(10) **Pub. No.: US 2019/0109293 A1**(43) **Pub. Date: Apr. 11, 2019**(54) **ORGANIC LIGHT-EMITTING DEVICE AND
DISPLAY DEVICE HAVING THE SAME**(30) **Foreign Application Priority Data**

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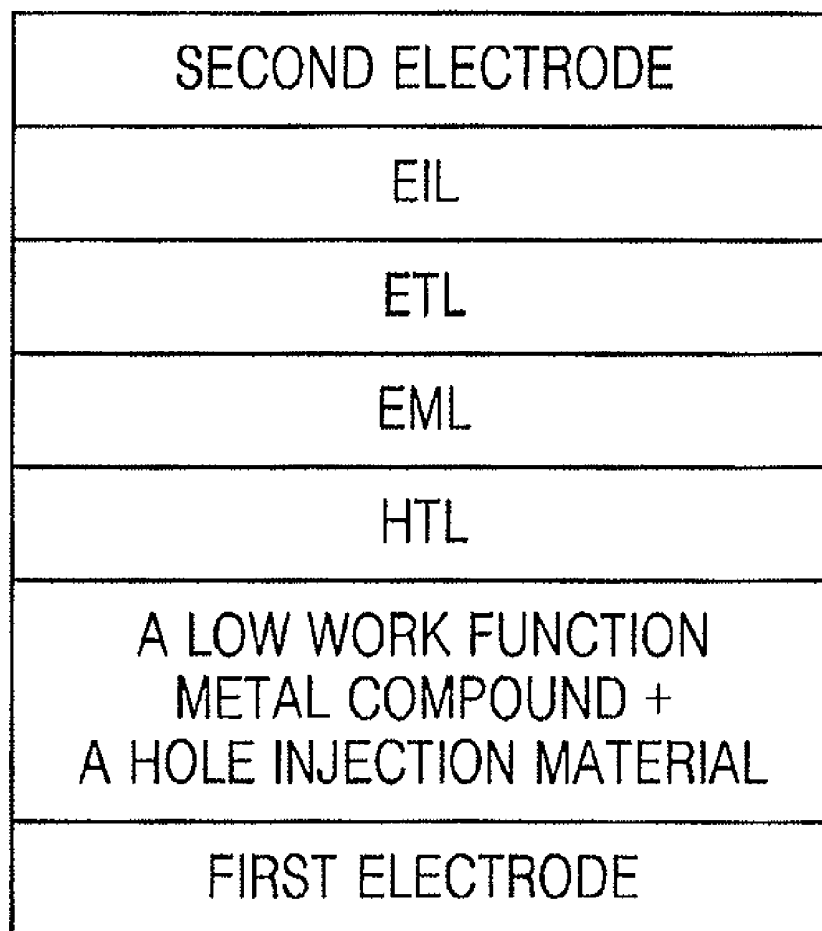
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Feb. 27, 2015, now Pat. No. 10,170,722.(57) **ABSTRACT**Provided is an organic light-emitting device including a first
electrode; a second electrode facing the first electrode; and
an organic layer between the first electrode and the second
electrode and including an emission layer, the organic layer
including a low work function metal compound.

FIG. 1

10

190
150
110

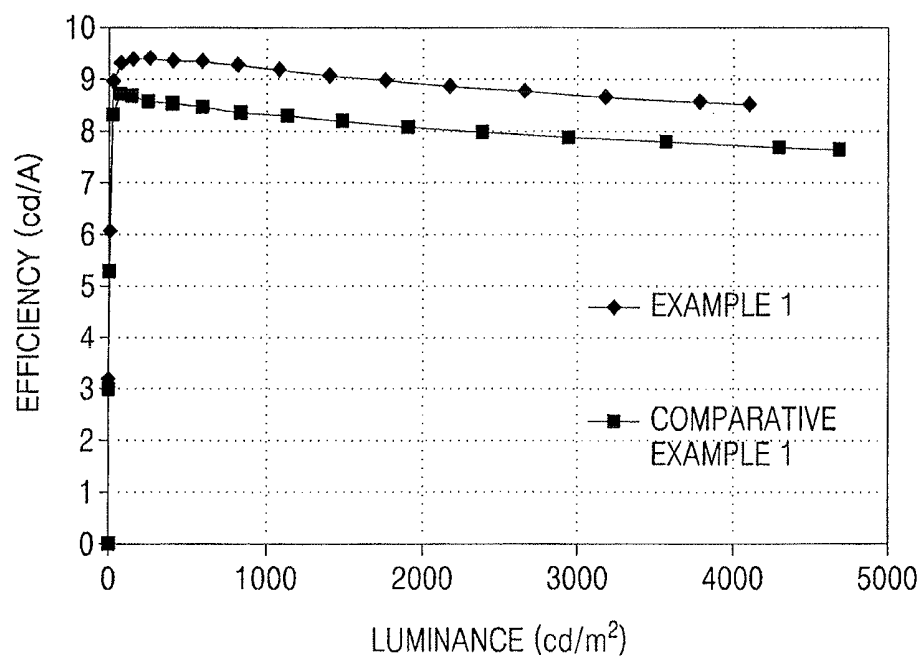
FIG. 2

SECOND ELECTRODE
EIL
ETL
EML
HTL
A LOW WORK FUNCTION METAL COMPOUND
FIRST ELECTRODE

FIG. 3

SECOND ELECTRODE
EIL
ETL
EML
HTL
A LOW WORK FUNCTION METAL COMPOUND + A HOLE INJECTION MATERIAL
FIRST ELECTRODE

FIG. 4



ORGANIC LIGHT-EMITTING DEVICE AND DISPLAY DEVICE HAVING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This is a continuation application based on pending application Ser. No. 14/633,365, filed Feb. 27, 2015, the entire contents of which is hereby incorporated by reference.

[0002] Korean Patent Application No. 10-2014-0122935, filed on Sep. 16, 2014, in the Korean Intellectual Property Office, and entitled: "Organic Light-Emitting Device," is incorporated by reference herein in its entirety.

BACKGROUND

1. Field

[0003] One or more exemplary embodiments relate to an organic light-emitting device.

2. Description of the Related Art

[0004] Organic light-emitting devices are self-emission devices that may have wide viewing angles, high contrast ratios, short response times, and excellent brightness, driving voltage, and response speed characteristics, and may produce full-color images.

SUMMARY

[0005] Embodiments may be realized by providing an organic light-emitting device, including a first electrode; a second electrode facing the first electrode; and an organic layer between the first electrode and the second electrode and including an emission layer, the organic layer including a low work function metal compound.

[0006] The low work function metal compound may have a work function in a range of more than 0 eV to about 3 eV.

[0007] The low work function metal compound may include a halide of an alkali metal.

[0008] The low work function metal compound may include a halide of an alkaline earth metal.

[0009] The low work function metal compound may include a halide of a lanthanide metal.

[0010] The low work function metal compound may include a halide of Li, Na, K, Rb, Cs, Be, Mg, Ca, Sr, Ba, Yb, or Sm.

[0011] The low work function metal compound may include LiF, NaF, KF, RbF, CsF, BeF₂, MgF₂, CaF₂, SrF₂, BaF₂, YbF, YbF₂, YbF₃, or SmF₃.

[0012] The low work function metal compound may include LiCl, NaCl, KCl, RbCl, CsCl, BeCl₂, MgCl₂, CaCl₂, SrCl₂, BaCl₂, YbCl, YbCl₂, YbCl₃, or SmCl₃.

[0013] The low work function metal compound may include LiBr, NaBr, KBr, RbBr, CsBr, BeBr₂, MgBr₂, CaBr₂, SrBr₂, BaBr₂, YbBr, YbBr₂, YbBr₃, or SmBr₃.

[0014] The low work function metal compound may include LiI, NaI, KI, RbI, CsI, BeI₂, MgI₂, CaI₂, SrI₂, BaI₂, YbI, YbI₂, YbI₃, or SmI₃.

[0015] The first electrode may be an anode, the second electrode may be a cathode, and the organic layer may include a layer including the low work function metal compound, a hole transport region between the first electrode and the emission layer, and including one or more of a hole injection layer, a hole transport layer, or an electron blocking layer, and an electron transport region between the

emission layer and the second electrode, and including one or more of a hole blocking layer, an electron transport layer, or an electron injection layer.

[0016] The layer including the low work function metal compound may be in the hole transport region.

[0017] The layer including the low work function metal compound may consist of a low work function metal compound.

[0018] The thickness of the layer including the low work function metal compound may be in a range of about 1 Å to about 30 Å.

[0019] The layer including the low work function metal compound may consist of a low work function metal compound and a hole injection material.

[0020] The thickness of the layer including the low work function metal compound may be in a range of about 1 Å to about 100 Å.

[0021] The layer including the low work function metal compound may contact an anode.

[0022] The layer including the low work function metal compound may consist of a low work function metal compound.

[0023] The layer including the low work function metal compound may consist of a low work function metal compound and a hole injection material.

[0024] Embodiments may be realized by providing a flat display apparatus, including the presently disclosed organic light-emitting device. The first electrode of the organic light-emitting device may be electrically connected to a source or drain electrode of a thin film transistor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] Features will become apparent to those of skill in the art by describing in detail exemplary embodiments with reference to the attached drawings in which:

[0026] FIG. 1 illustrates a schematic view of an organic light-emitting device according to an embodiment;

[0027] FIG. 2 illustrates a schematic cross-sectional view of an organic light-emitting device according to an embodiment;

[0028] FIG. 3 illustrates a schematic cross-sectional view of an organic light-emitting device according to an embodiment; and

[0029] FIG. 4 illustrates a graph of an efficiency of each of the devices of Example 1 and Comparative Example 1.

DETAILED DESCRIPTION

[0030] Example embodiments will now be described more fully hereinafter with reference to the accompanying drawings; however, they may be embodied in different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey exemplary implementations to those skilled in the art.

[0031] In the drawing figures, the dimensions of layers and regions may be exaggerated for clarity of illustration. It will also be understood that when a layer or element is referred to as being "on" another layer or substrate, it can be directly on the other layer or substrate, or intervening layers may also be present. Further, it will be understood that when a layer is referred to as being "under" another layer, it can be directly under, and one or more intervening layers may

also be present. In addition, it will also be understood that when a layer is referred to as being “between” two layers, it can be the only layer between the two layers, or one or more intervening layers may also be present. Like reference numerals refer to like elements throughout.

[0032] An organic light-emitting device according to an aspect of some embodiments includes:

[0033] a first electrode;

[0034] a second electrode facing the first electrode; and

[0035] an organic layer disposed between the first electrode and the second electrode and including an emission layer,

[0036] wherein the organic layer includes a layer including a low work function metal compound.

[0037] A hole injection layer including CuI having a high work function may be used to provide a device that may lower an energy barrier of an anode and the hole injection layer.

[0038] A hole injection barrier may be lowered when an organic light-emitting device includes a layer including a low work function metal compound. However, in a case in which the low work function metal compound dissociates, the low work function metal compound may rather increase an energy barrier. In this regard, a metal compound used herein may have a strong binding force.

[0039] In some embodiments, the low work function metal compound may have a work function in a range of more than 0 eV to about 3 eV.

[0040] In some embodiments, the low work function metal compound may include a halide of an alkali metal, a halide of an alkaline earth metal, or a halide of a lanthanide metal.

[0041] In some embodiments, the low work function metal compound may include a halide of Li, Na, K, Rb, Cs, Be, Mg, Ca, Sr, Ba, Yb, or Sm.

[0042] In some embodiments, the low work function metal compound may include LiCl, NaCl, KCl, RbCl, CsCl, BeCl₂, MgCl₂, CaCl₂, SrCl₂, BaCl₂, YbCl, YbCl₂, YbCl₃, SmCl₃, LiBr, NaBr, KBr, RbBr, CsBr, BeBr₂, MgBr₂, CaBr₂, SrBr₂, BaBr₂, YbBr, YbBr₂, YbBr₃, SmBr₃, LiI, NaI, KI, RbI, CsI, BeI₂, MgI₂, CaI₂, SrI₂, BaI₂, YbI, YbI₂, YbI₃, or SmI₃. For example, the low work function metal compound may include LiI, NaI, KI, RbI, or CsI.

[0043] In some embodiments, in the organic light-emitting device, the first electrode may be an anode, the second electrode may be a cathode, and the organic layer may include:

[0044] i) a layer including a low work function metal compound,

[0045] ii) a hole transport region disposed between the first electrode and the emission layer, and including at least one selected from a hole injection layer, a hole transport layer, and an electron blocking layer, and

[0046] iii) an electron transport region disposed between the emission layer and the second electrode, and including at least one selected from a hole blocking layer, an electron transport layer, and an electron injection layer.

[0047] In some embodiments, the layer including the low work function metal compound may be disposed in the hole transport region.

[0048] In some embodiments, the layer including the low work function metal compound may be formed of a low work function metal compound. The layer including the low work function metal compound may include only a low work function metal compound.

[0049] In some embodiments, the thickness of the layer that includes only a low work function metal compound may be in a range of about 1 Å to about 30 Å.

[0050] The organic light-emitting device may have a maximum efficiency when the thickness of the layer is maintained within the aforementioned range.

[0051] In some embodiments, the layer including a low work function metal compound may be formed of a low work function metal compound and a hole injection material. The thickness of the layer formed of a low work function metal compound and a hole injection material may be in a range of about 1 Å to about 100 Å.

[0052] The organic light-emitting device may have a maximum efficiency when the thickness of the layer is maintained within the aforementioned range.

[0053] The volume percent ratio of low work function metal compound:hole injection material may be in a range of about 1:60 to about 60:1. For example, the volume percent ratio may be in a range of about 1:50 to about 50:1. The organic light-emitting device may have a maximum efficiency when the volume percent ratio thereof is maintained within the aforementioned range. For example, the low work function metal compound and the hole injection material might be codeposited in volume unit.

[0054] A low work function metal compound may be co-deposited on the hole transport layer, the low work function metal compound may take electrons from a hole transport material, and p-doping may occur.

[0055] In some embodiments, the layer including a low work function metal compound may contact an anode. The layer including the low work function metal compound may be formed of only a low work function metal compound, or of a low work function metal compound and a hole injection material.

[0056] The expression “(an organic layer) includes at least one group represented by Formula x” used herein may include identical group represented by Formula x and two or more different group represented by Formula x.

[0057] 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. Materials included in the “organic layer” are not limited to organic materials.

[0058] FIG. 1 illustrates a schematic view of an organic light-emitting device 10 according to an embodiment. The organic light-emitting device 10 may include a first electrode 110, an organic layer 150, and a second electrode 190.

[0059] Hereinafter, the structure of an organic light-emitting device according to an embodiment and a method of manufacturing an organic light-emitting device according to an embodiment will be described in connection with FIG. 1.

[0060] In FIG. 1, 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 transparent plastic substrate, each with excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and water repellency.

[0061] The first electrode 110 may be formed by depositing or sputtering a material for forming the first electrode on the substrate. When the first electrode 110 is an anode, the material for the first electrode 110 may be selected from materials having a high work function to make holes be easily injected. The first electrode 110 may be a reflective electrode, a semi-transmissive electrode or a transmissive

electrode. The material for the first electrode **110** may be a transparent and highly conductive material, and examples of such a material are indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO_2), and zinc oxide (ZnO). When the first electrode **110** is a semi-transmissive electrode or a reflective electrode, as a material for forming the first electrode, at least one selected from magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), and magnesium-silver (Mg—Ag) may be used.

[0062] The first electrode **110** may have a single-layer structure, or a multi-layer structure including two or more layers. For example, the first electrode **110** may have a three-layered structure of ITO/Ag/ITO.

[0063] The organic layer **150** may be disposed on the first electrode **110**. The organic layer **150** may include an emission layer. A layer including a low work function metal compound may contact the first electrode **110**.

[0064] The organic layer **150** may further include a hole transport region disposed between the first electrode and the emission layer, and an electron transport region disposed between the emission layer and the second electrode.

[0065] The hole transport region may include, for example, a layer including a low work function metal compound, and at least one selected from a hole transport layer (HTL), a hole injection layer (HIL), and a buffer, and the electron transport region may include, for example, at least one selected from a hole blocking layer (HBL), an electron transport layer (ETL), and an electron injection layer (EIL).

[0066] According to an embodiment, the hole injection layer may be a layer formed of a low work function metal compound; or a layer formed of a low work function metal compound and a hole injection material.

[0067] The hole transport region may have a single-layered structure formed of a single material, a single-layered structure formed of a plurality of different materials, or a multi-layered structure having a plurality of layers formed of a plurality of different materials.

[0068] For example, the hole transport region may have a single-layered structure formed of a plurality of different materials, or may have a structure of a layer formed of only a low work function metal compound/hole transport layer, a layer formed of a low work function metal compound and a hole injection material/hole transport layer, a layer formed of a low work function metal compound and a hole injection material/hole transport layer/buffer layer, a hole injection layer/buffer layer, a hole transport layer/buffer layer, or a hole injection layer/hole transport layer/electron blocking layer. In each structure of the hole transport region, constituting layers may be, for example, sequentially stacked from the first electrode **110** in the stated order.

[0069] When the hole transport region includes a hole injection layer, the hole injection layer may be formed on the first electrode **110** using various methods, such as vacuum deposition, spin coating casting, a Langmuir-Blodgett (LB) method, ink-jet printing, laser-printing, or laser-induced thermal imaging.

[0070] When a hole injection layer is formed by vacuum deposition, for example, the vacuum deposition may be performed at a temperature of a deposition temperature of about 100 to about 500° C., at a vacuum degree of about 10^{-8} to about 10^{-3} torr, and at a deposition rate of about 0.01

to about 100 Å/sec in consideration of a compound for a hole injection layer to be deposited, and the structure of a hole injection layer to be formed.

[0071] When a hole injection layer is formed by spin coating, the spin coating may be performed at a coating rate of about 2000 rpm to about 5000 rpm, and at a temperature of about 80° C. to 200° C. in consideration of a compound for a hole injection layer to be deposited, and the structure of a hole injection layer to be formed.

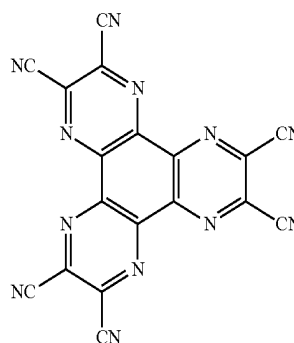
[0072] When the hole transport region includes a hole transport layer, the hole transport layer may be formed on the first electrode **110** or the hole injection layer using various methods, such as vacuum deposition, spin coating, casting, a LB method, ink-jet printing, laser-printing, or laser-induced thermal imaging. When the hole transport layer is formed by vacuum deposition or spin coating, deposition and coating conditions for the hole transport layer may be the same as the deposition and coating conditions for the hole injection layer.

[0073] 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 1000 Å. When the hole transport region includes both 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 10000 Å, for example, about 100 Å to about 1000 Å, and a thickness of the hole transport layer may be in a range of about 50 Å to about 2000 Å, for example about 100 Å to about 1500 Å. When the thicknesses of the hole transport region, the hole injection layer, and the hole transport layer are within these ranges, satisfactory hole transporting characteristics may be provided without a substantial increase in driving voltage.

[0074] 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.

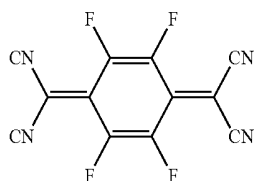
[0075] The charge-generation material may be, for example, a p-dopant. The p-dopant may be one of, for example, a quinone derivative, a metal oxide, and a cyano group-containing compound. Examples of the p-dopant include a quinone derivative, such as, for example, tetracyanoquinonodimethane (TCNQ) or 2,3,5,6-tetrafluoro-tetracyano-1,4-benzoquinonodimethane (F4-TCNQ); a metal oxide, such as for example, a tungsten oxide or a molybdenum oxide, and Compound HT-D1 illustrated below.

<Compound HT-D1>



-continued

<F4-TCNQ>



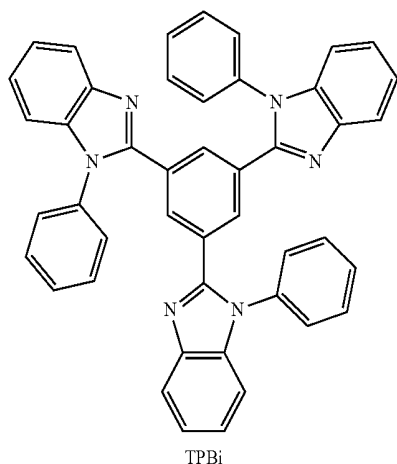
[0076] The hole transport region may further include a buffer layer, in addition to an electron blocking layer, a hole injection layer, and a hole transport layer. The buffer layer may compensate for an optical resonance distance according to a wavelength of light emitted from the emission layer, and light-emission efficiency of a formed organic light-emitting device may be improved. For use as a material included in the buffer layer, materials that are included in the hole transport region may be used. The electron blocking layer may prevent injection of electrons from the electron transport region.

[0077] An emission layer is formed on the first electrode 110 or the hole transport region using various methods, such as vacuum deposition, spin coating, casting, a LB method, ink-jet printing, laser-printing, or laser-induced thermal imaging. When an emission layer is formed by vacuum deposition or spin coating, deposition and coating conditions for the emission may be the same as those for the hole injection layer.

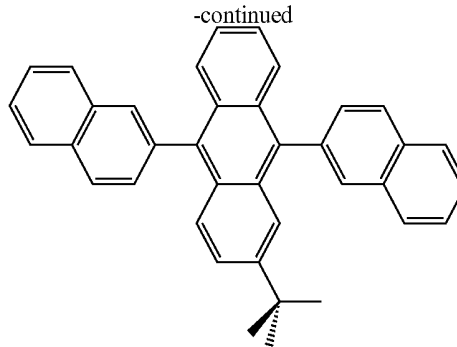
[0078] When the organic light-emitting device 10 is a full color organic light-emitting device, the emission layer may be patterned into a red emission layer, a green emission layer, or a blue emission layer, according to a sub pixel. In some embodiments, the emission layer may have a stacked structure of a red emission layer, a green emission layer, and a blue emission layer, or may include a red-light emission material, a green-light emission material, and a blue-light emission material, which are mixed with each other in a single layer, to emit white light.

[0079] The emission layer may include a host and a dopant.

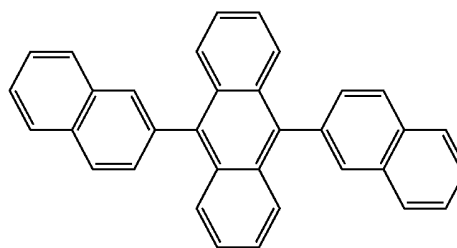
[0080] The host may include at least one selected from, for example, TPBi, TBADN, AND (also referred to as "DNA"), CBP, CDBP and TCP below:



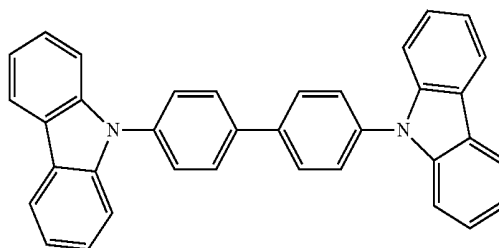
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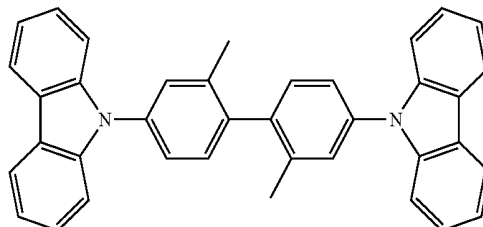
TBADN



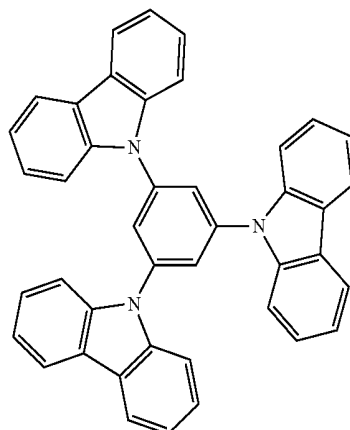
ADN



CBP

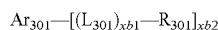


CDBP



TCP

[0081] According to an embodiment, the host may include a group represented by Formula 301 below:



<Formula 301>

[0082] wherein in Formula 301,

[0083] Ar₃₀₁ may be selected from

[0084] a naphthalene, a heptalene, a fluorene, a spiro-fluorene, a benzofluorene, a dibenzofluorene, a phenalene, a phenanthrene, an anthracene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a naphthacene, a picene, a perylene, a pentaphene, and an indenoanthracene; and

[0085] a naphthalene, a heptalene, a fluorene, a spiro-fluorene, a benzofluorene, a dibenzofluorene, a phenalene, a phenanthrene, an anthracene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a naphthacene, a picene, a perylene, a pentaphene, and an indenoanthracene, each substituted with at least one selected from a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₂-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₂-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₂-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, monovalent non-aromatic condensed heteropolycyclic group, and —Si(Q₃₀₁)(Q₃₀₂)(Q₃₀₃) (Q₃₀₁ to Q₃₀₃ may be each independently selected from a hydrogen, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₆-C₆₀ aryl group, and a C₂-C₆₀ heteroaryl group);

[0086] L₃₀₁ may be selected from a substituted or unsubstituted C₃-C₁₀ cycloalkylene group, a substituted or unsubstituted C₂-C₁₀ heterocycloalkylene group, a substituted or unsubstituted C₃-C₁₀ cycloalkenylene group, a substituted or unsubstituted C₂-C₁₀ heterocycloalkenylene group, a substituted or unsubstituted C₆-C₆₀ arylene group, a substituted or unsubstituted C₂-C₆₀ heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group;

[0087] R₃₀₁ may be selected from

[0088] a C₁-C₂₀ alkyl group and a C₁-C₂₀ alkoxy group;

[0089] a C₁-C₂₀ alkyl group and a C₁-C₂₀ alkoxy group, each substituted with at least one selected from a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

[0090] a phenyl group, a naphthyl group, a fluorenyl group, a Spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

[0091] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a

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

[0092] xb1 may be selected from 0, 1, 2, and 3;

[0093] xb2 may be selected from 1, 2, 3, and 4.

[0094] For example, in Formula 301

[0095] L₃₀₁ may be selected from

[0096] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, and a chrysenylene group; and

[0097] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, and a chrysenylene group, each substituted with at least one selected from a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, and a chrysenyl group;

[0098] R₃₀₁ may be selected from

[0099] a C₁-C₂₀ alkyl group and a C₁-C₂₀ alkoxy group;

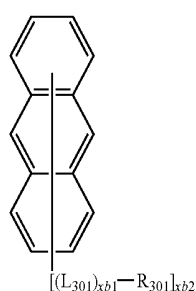
[0100] a C₁-C₂₀ alkyl group and a C₁-C₂₀ alkoxy group, each substituted with at least one selected from a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, and a chrysenyl group;

[0101] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, and a chrysenyl group; and

[0102] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, and a chrysenyl group, each substituted with at least one selected from a deuterium, —F,

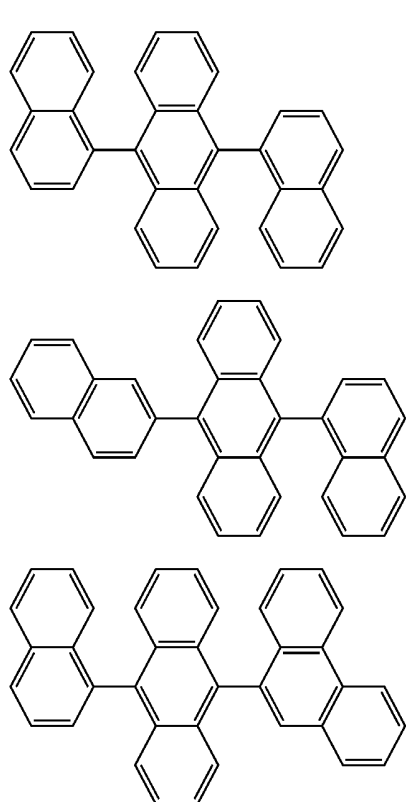
—Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1 - C_{20} alkyl group, a C_1 - C_{20} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, and a chrysenyl group.

[0103] For example, the host may include a group represented by Formula 301A below:

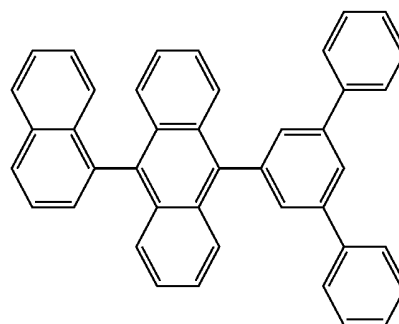
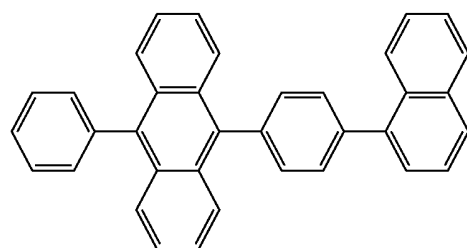
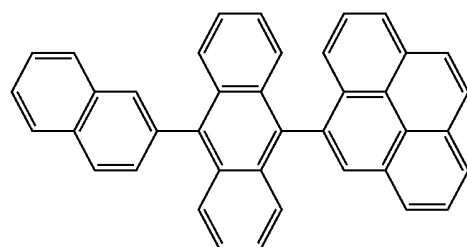
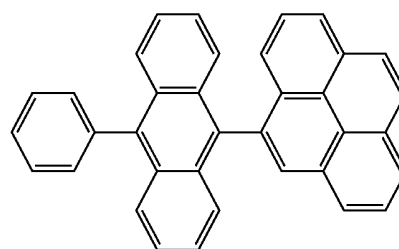
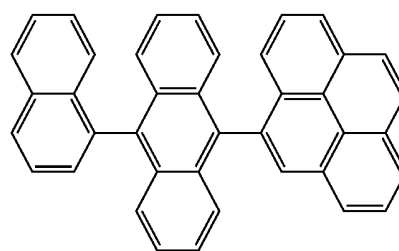
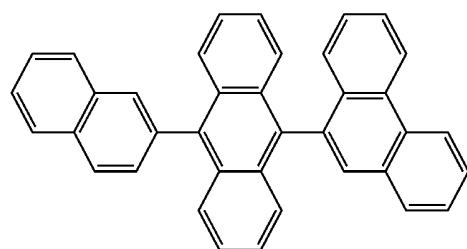


[0104] Substituents of Formula 301A may be understood by corresponding descriptions provided herein.

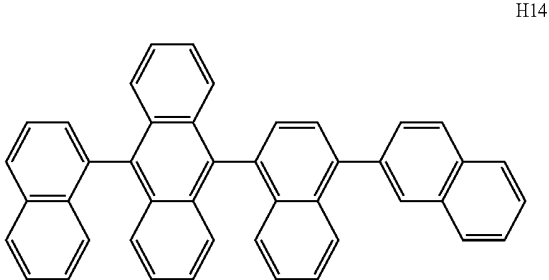
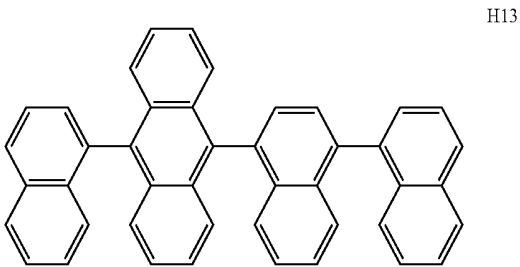
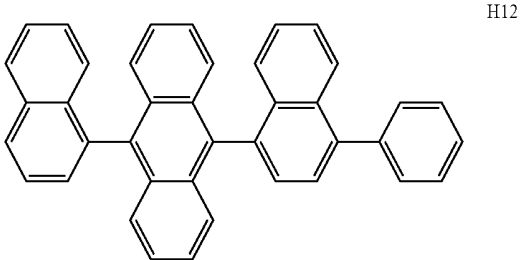
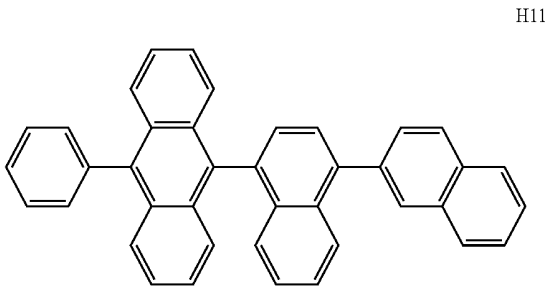
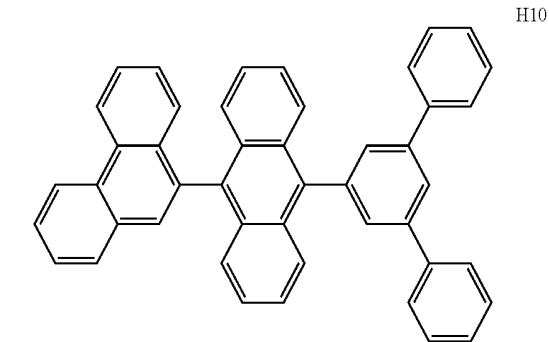
[0105] The group represented by Formula 301 may include, for example, at least one selected from Compounds H1 to H42:



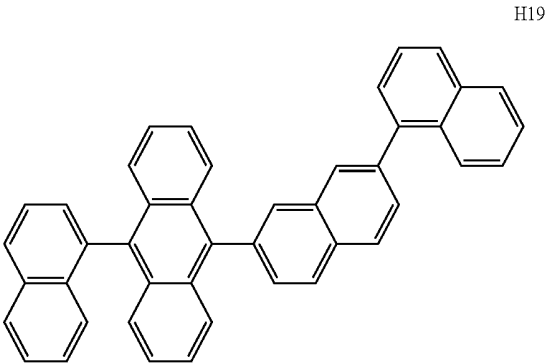
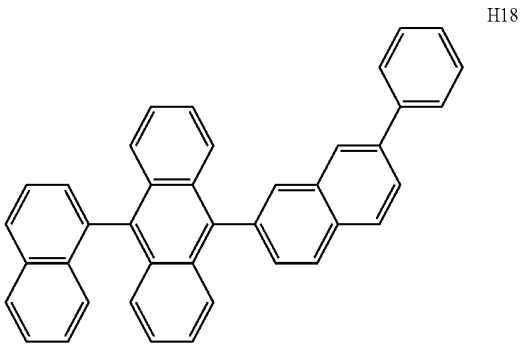
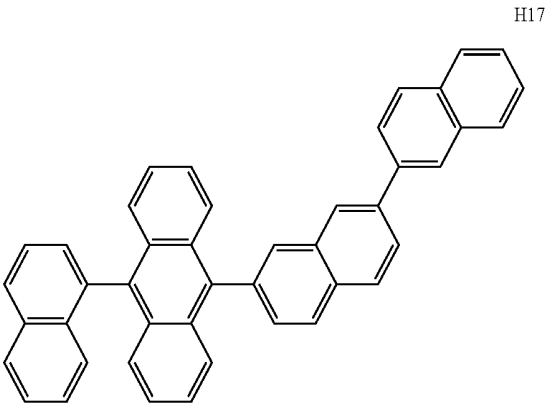
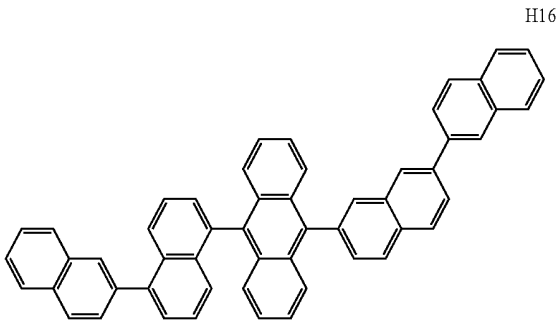
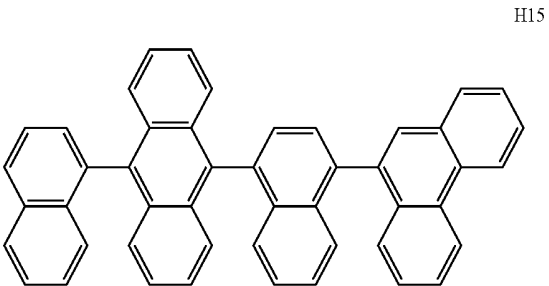
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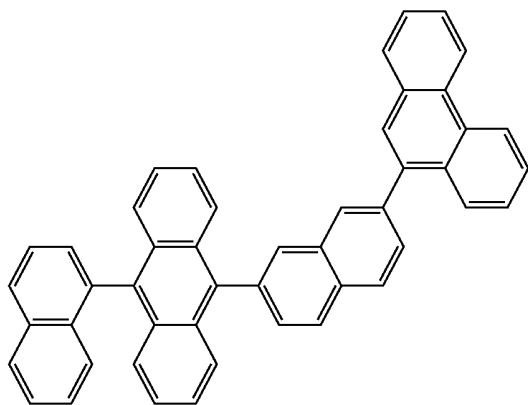


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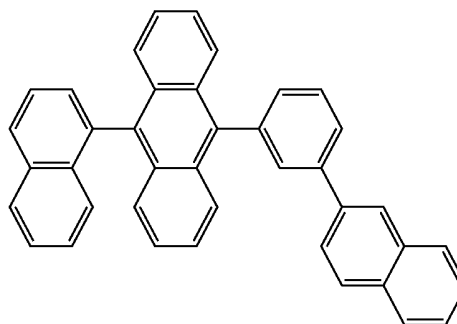
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H20

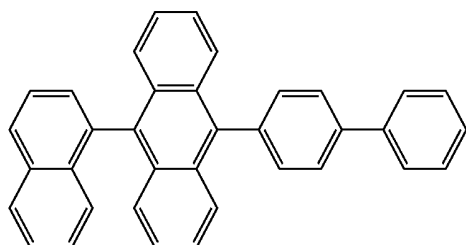


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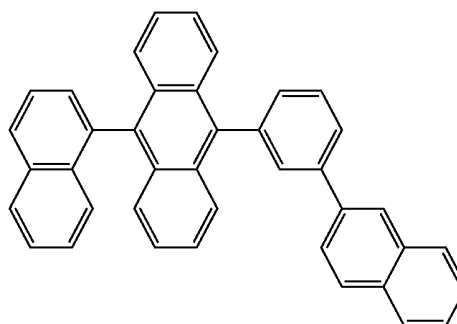
H25



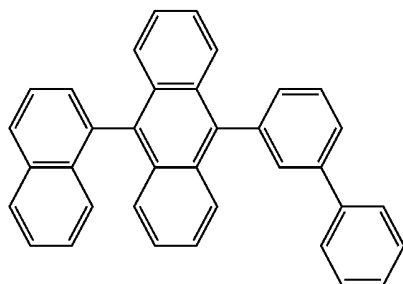
H21



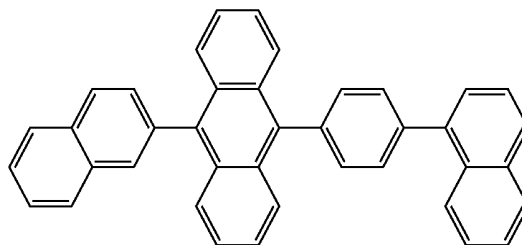
H26



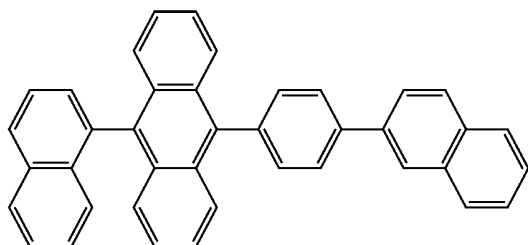
H22



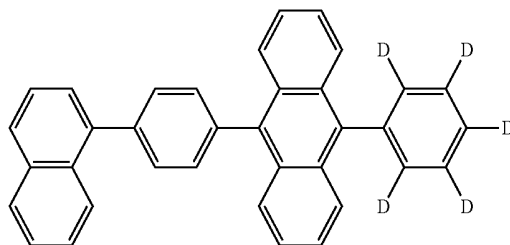
H27



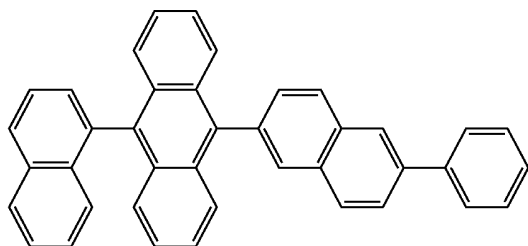
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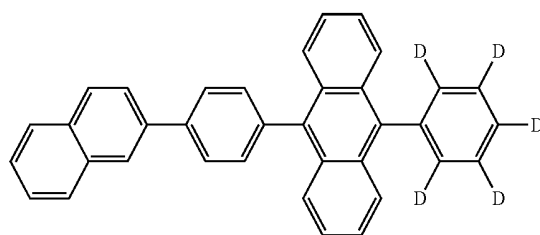
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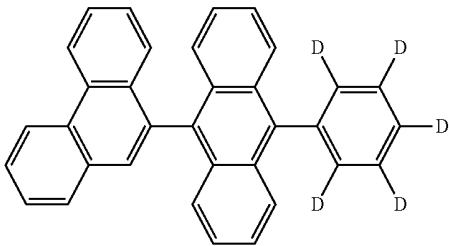
H24



H29

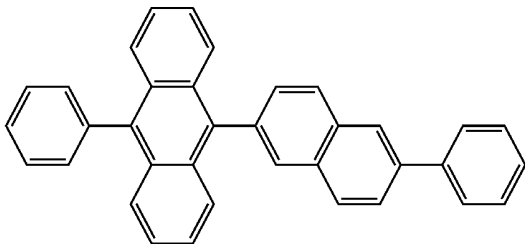


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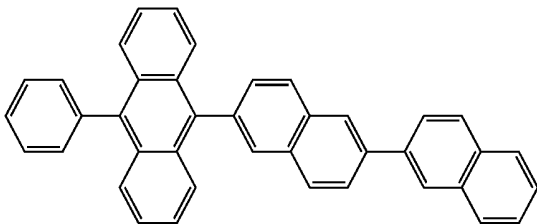


H30

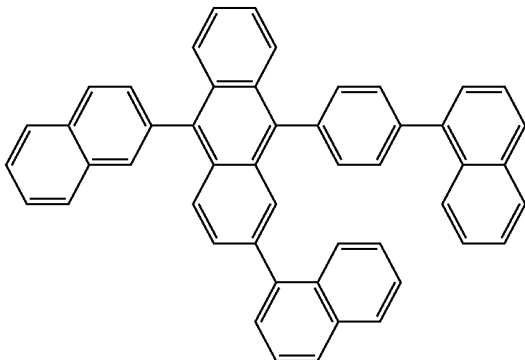
H31



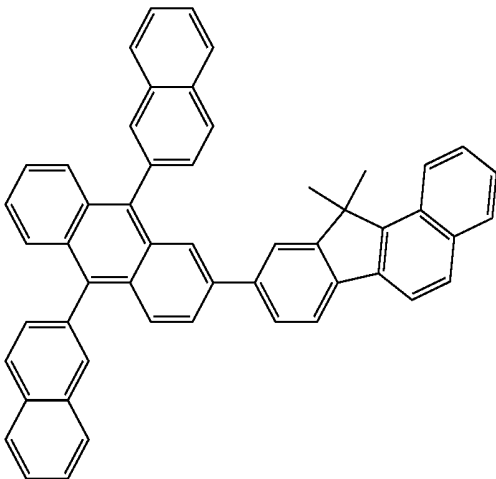
H32



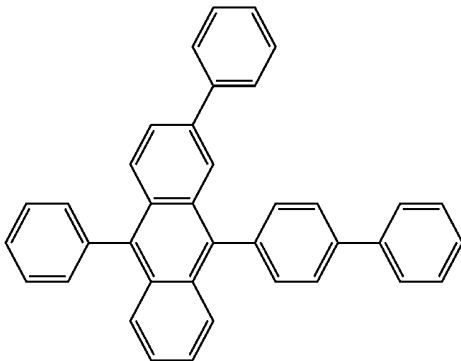
H33



H34

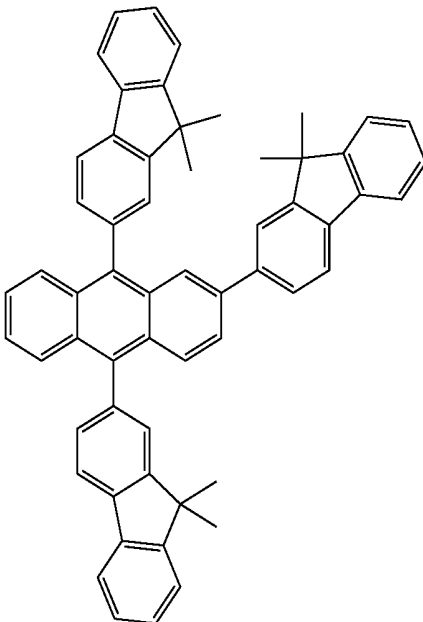


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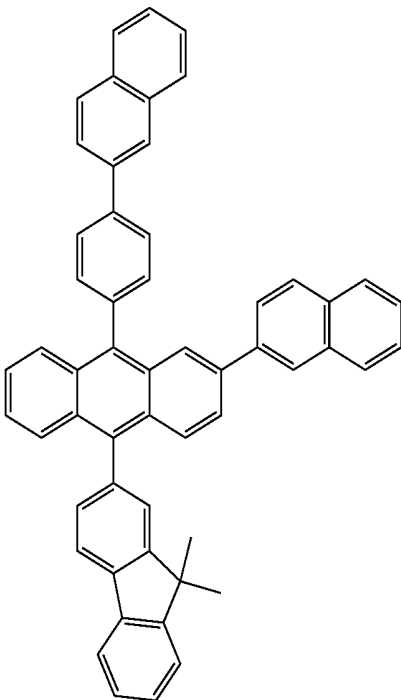


H35

H36



H37

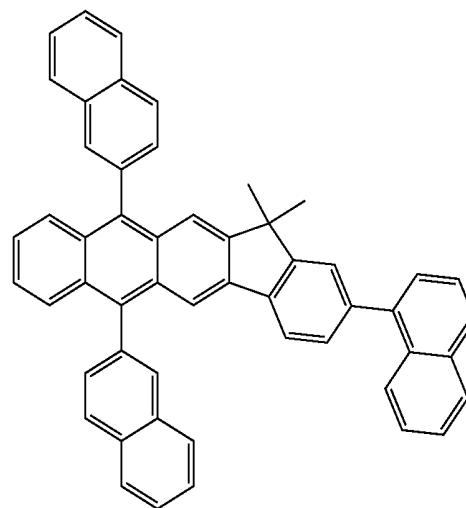
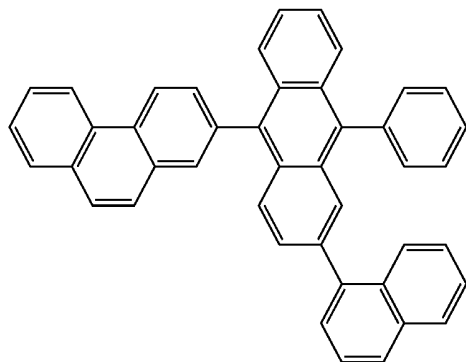


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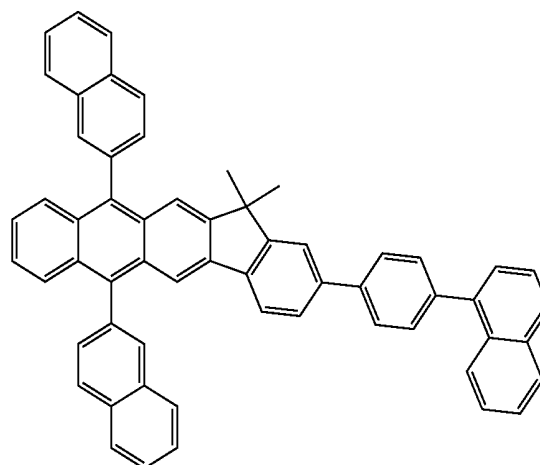
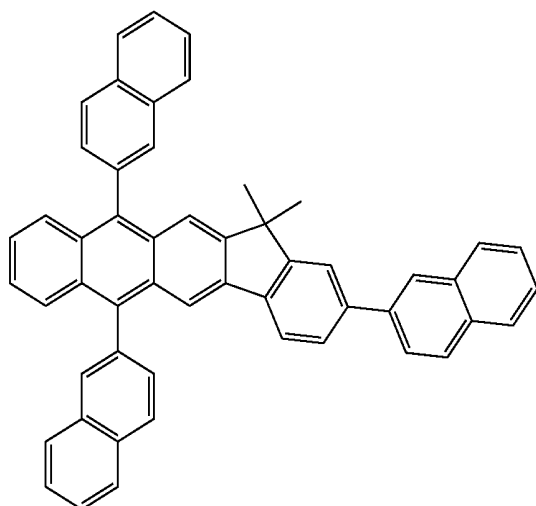
H41

H38



H39

H42



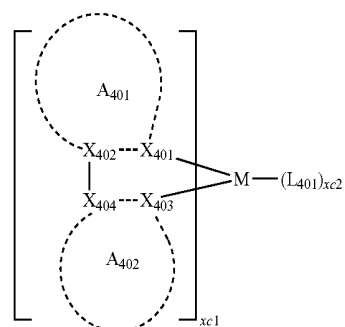
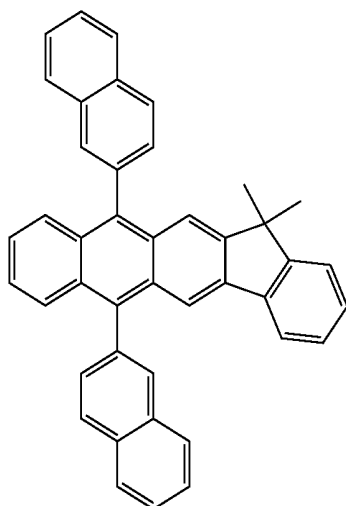
H40

[0106] The dopant may be at least one selected from a fluorescent dopant and a phosphorescent dopant.

[0107] The phosphorescent dopant may include an organometallic complex represented by

[0108] Formula 401 below:

<Formula 401>



[0109] wherein in Formula 401,

[0110] M may be selected from iridium (Ir), platinum (Pt), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), and thulium (Tm);

[0111] X_{401} to X_{404} may be each independently nitrogen or carbon;

[0112] A_{401} and A_{402} rings may be each independently selected from a substituted or unsubstituted benzene group, a substituted or unsubstituted naphthalene group, a substituted or unsubstituted fluorene group, a substituted or unsubstituted spiro-fluorene group, a substituted or unsubstituted indene group, a substituted or unsubstituted pyrrol group, a substituted or unsubstituted thiophene group, a substituted or unsubstituted furan group, a substituted or unsubstituted imidazole group, a substituted or unsubstituted pyrazole group, a substituted or unsubstituted thiazole group, a substituted or unsubstituted isothiazole group, a substituted or unsubstituted oxazole group, a substituted or unsubstituted isoxazole group, a substituted or unsubstituted pyridine group, a substituted or unsubstituted pyrazine group, a substituted or unsubstituted pyrimidine group, a substituted or unsubstituted pyridazine group, a substituted or unsubstituted quinoline group, a substituted or unsubstituted isoquinoline group, a substituted or unsubstituted benzoquinoline group, a substituted or unsubstituted quinoxaline group, a substituted or unsubstituted quinazoline group, a substituted or unsubstituted carbazol group, a substituted or unsubstituted benzimidazole group, a substituted or unsubstituted benzofuran group, a substituted or unsubstituted benzothiophene group, a substituted or unsubstituted isobenzothiophene group, a substituted or unsubstituted benzooxazole group, a substituted or unsubstituted isobenzooxazole group, a substituted or unsubstituted triazole group, a substituted or unsubstituted oxadiazole group, a substituted or unsubstituted triazine group, a substituted or unsubstituted dibenzofuran group, and a substituted or unsubstituted dibenzothiophene group; and

[0113] at least one substituent of the substituted benzene group, substituted naphthalene group, substituted fluorene group, substituted spiro-fluorene group, substituted indene group, substituted pyrrol group, substituted thiophene group, substituted furan group, substituted imidazole group, substituted pyrazole group, substituted thiazole group, substituted isothiazole group, substituted oxazole group, substituted isoxazole group, substituted pyridine group, substituted pyrazine group, substituted pyrimidine group, substituted pyridazine group, substituted quinoline group, substituted isoquinoline group, substituted benzoquinoline group, substituted quinoxaline group, substituted quinazoline group, substituted carbazol group, substituted benzimidazole group, substituted benzofuran group, substituted benzothiophene group, substituted isobenzothiophene group, substituted benzooxazole group, substituted isobenzooxazole group, substituted triazole group, substituted oxadiazole group, substituted triazine group, substituted dibenzofuran group, and substituted dibenzothiophene group may be selected from

[0114] a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60} alkynyl group, and a C_1 - C_{60} alkoxy group;

[0115] a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60} alkynyl group, and a C_1 - C_{60} alkoxy group, each substituted with at least one selected from a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro

group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_3 - C_{10} cycloalkyl group, a C_2 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_2 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_2 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q_{401})(Q_{402}), —Si(Q_{403})(Q_{404})(Q_{405}), and —B(Q_{406})(Q_{407});

[0116] a C_3 - C_{10} cycloalkyl group, a C_2 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_2 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_2 - C_{60} heteroaryl group, and a non-aromatic condensed polycyclic group;

[0117] a C_3 - C_{10} cycloalkyl group, a C_2 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_2 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_2 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60} alkynyl group, a C_1 - C_{60} alkoxy group, a C_3 - C_{10} cycloalkyl group, a C_2 - C_{10} heterocycloalkyl group, a C_3 - C_{10} cycloalkenyl group, a C_2 - C_{10} heterocycloalkenyl group, a C_6 - C_{60} aryl group, a C_6 - C_{60} aryloxy group, a C_6 - C_{60} arylthio group, a C_2 - C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q_{411})(Q_{412}), —Si(Q_{413})(Q_{414})(Q_{415}) and —B(Q_{416})(Q_{417}); and

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

[0118] L_{401} is an organic ligand;

[0119] xc1 is 1, 2, or 3; and

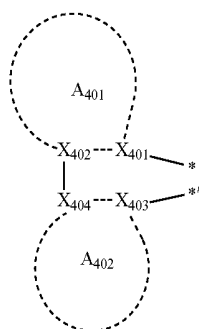
[0120] xc2 is 0, 1, 2, or 3.

[0121] L_{401} may be a monovalent, divalent, or trivalent organic ligand. For example, L_{401} may be selected from a halogen ligand (for example, Cl or F), a diketone ligand (for example, acetylacetonate, 1,3-diphenyl-1,3-propanedionate, 2,2,6,6-tetramethyl-3,5-heptanedionate, or hexafluoroacetonate), a carboxylic acid ligand (for example, picolinate, dimethyl-3-pyrazolecarboxylate, or benzoate), a carbon monoxide ligand, an isonitrile ligand, a cyano ligand, and a phosphorous ligand (for example, phosphine, and phosphite).

[0122] When A_{401} in Formula 401 has two or more substituents, the substituents of A_{401} may bind to each other to form a saturated or unsaturated ring.

[0123] When A_{401} in Formula 402 has two or more substituents, the substituents of A_{402} may bind to each other to form a saturated or unsaturated ring.

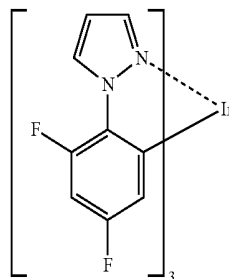
[0124] When xc1 in Formula 401 is two or more, a plurality of ligands



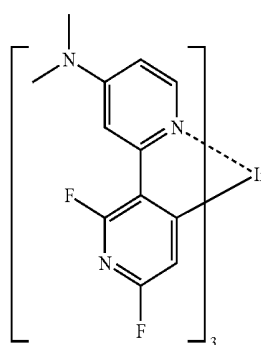
in Formula 401 may be identical or different. When xc1 in Formula 401 is two or more, A₄₀₁ and A₄₀₂ may be respectively directly connected to A₄₀₁ and A₄₀₂ of other neighboring ligands with or without a linker (for example, a C₁-C₅ alkylene, or —N(R')— (wherein R' may be a C₁-C₁₀ alkyl group or a C₆-C₂₀ aryl group) or —C(=O)—) therebetween.

[0125] The phosphorescent dopant may include, for example, at least one selected from Compounds PD1 to PD74 below:

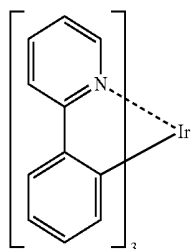
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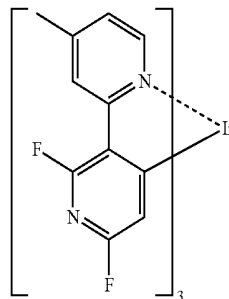
PD4



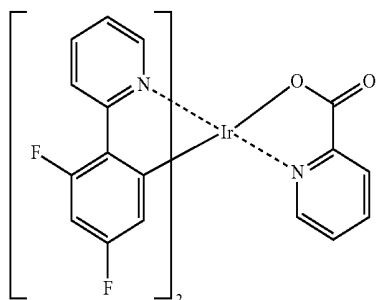
PD5



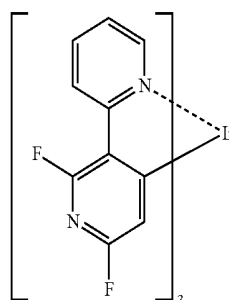
PD1



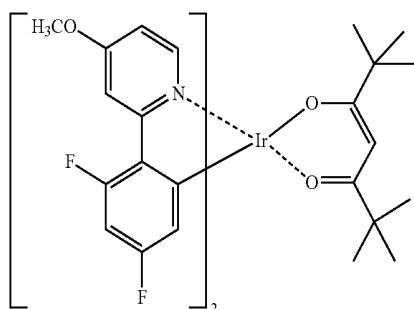
PD6



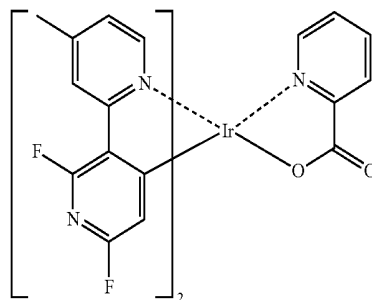
PD2



PD7

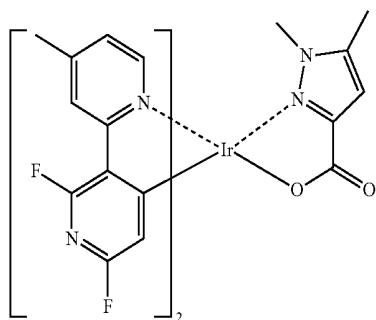


PD3



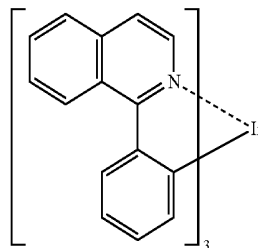
PD8

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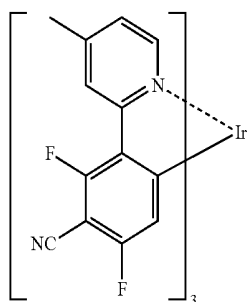


PD9

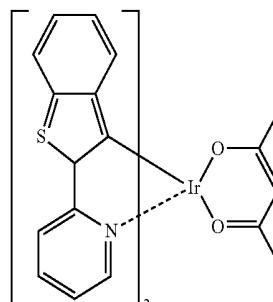
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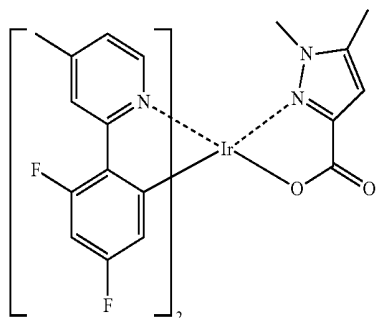
PD14



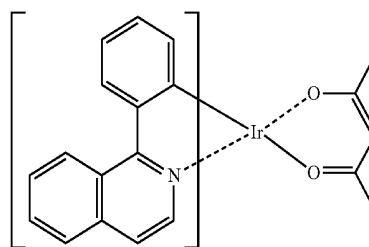
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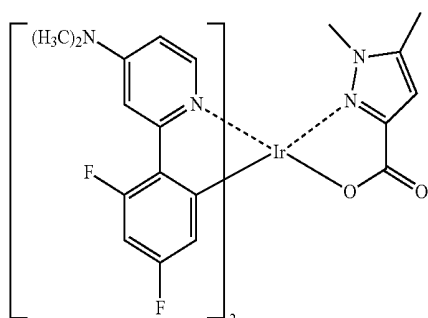
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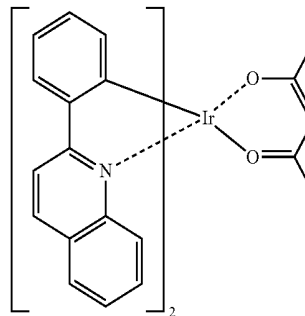
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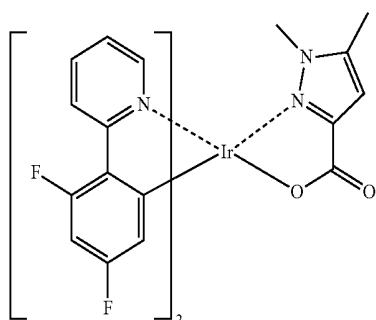
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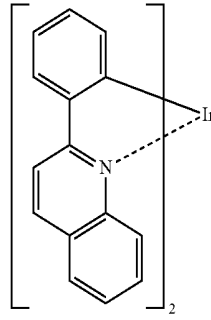
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PD17

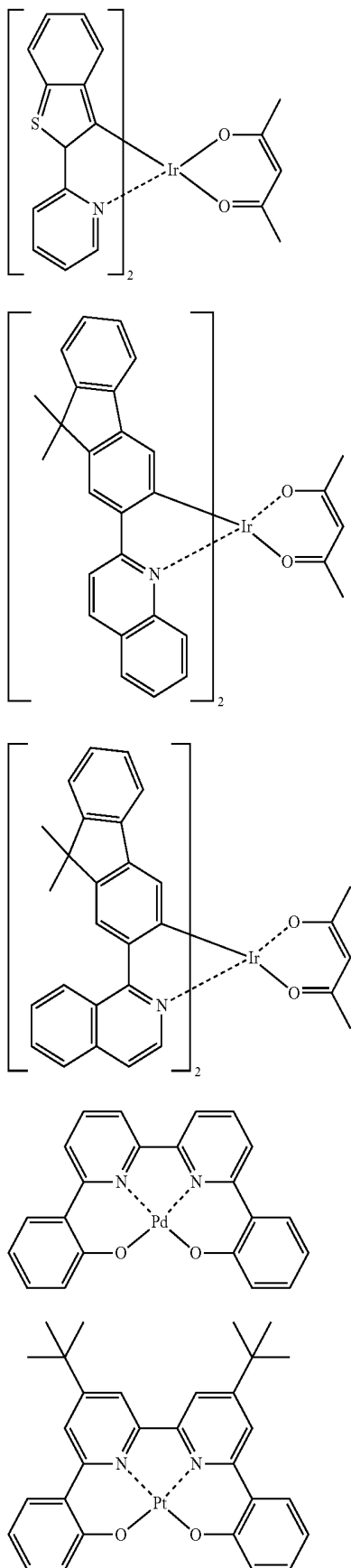


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PD18

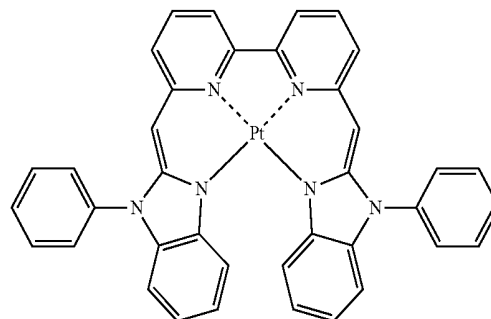
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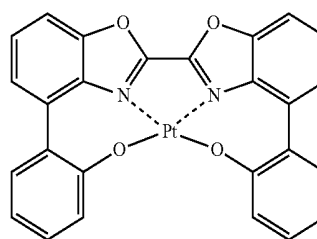
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PD24



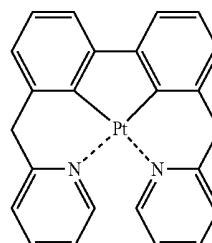
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PD25



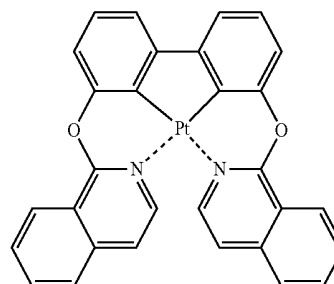
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PD26



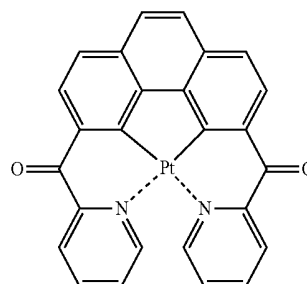
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PD27

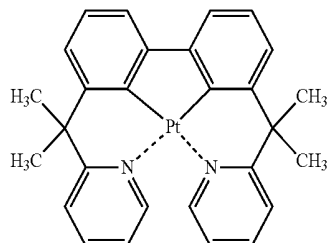


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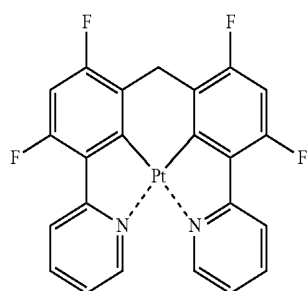
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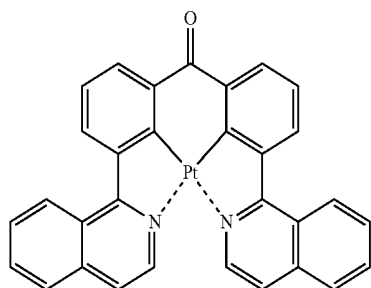
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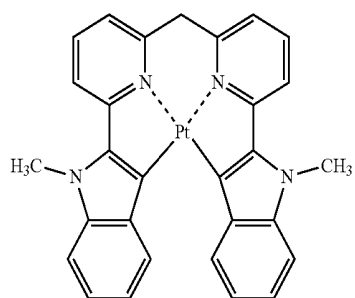
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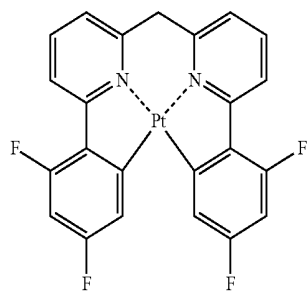
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PD31

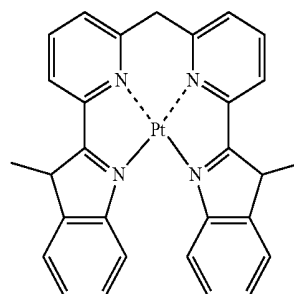


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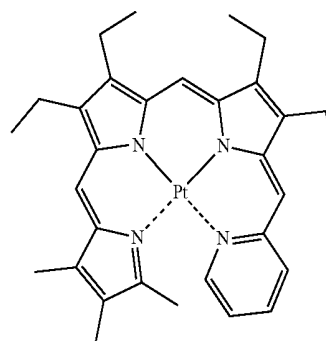


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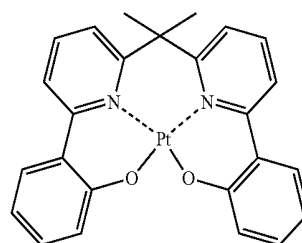
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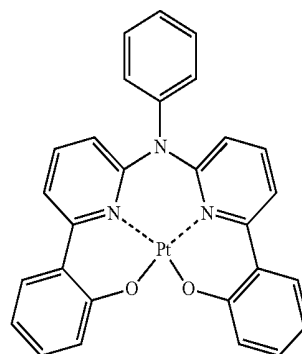
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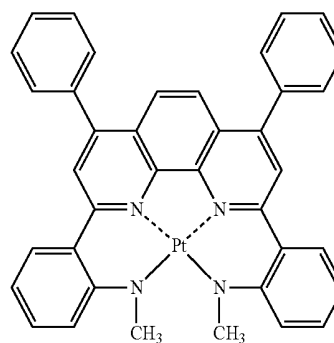
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PD36

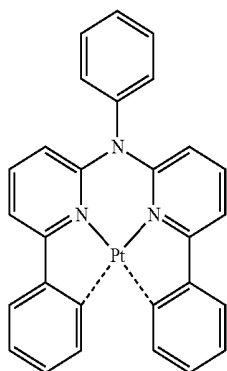
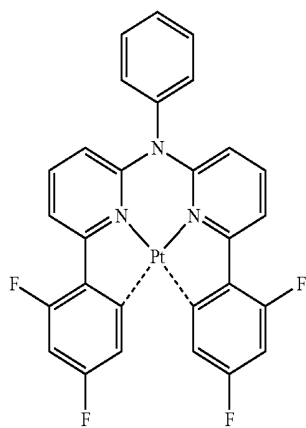
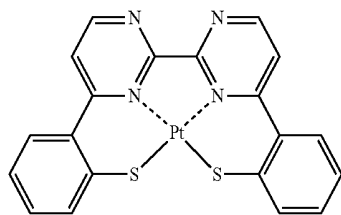
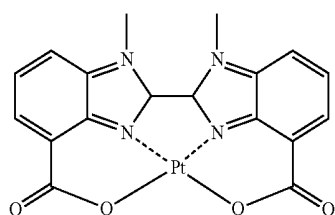
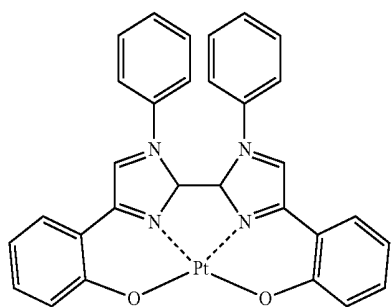


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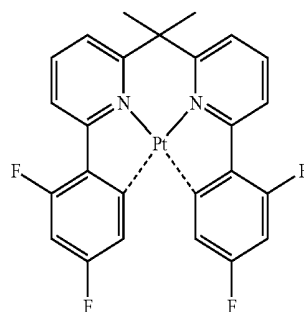
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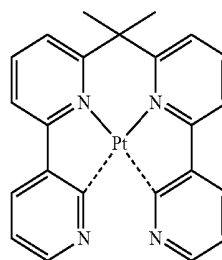
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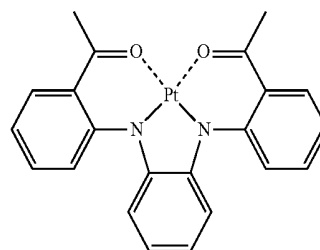
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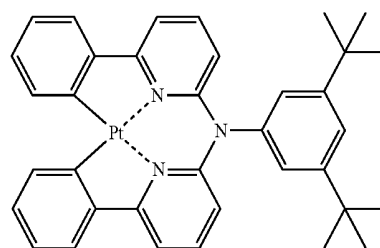
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PD41



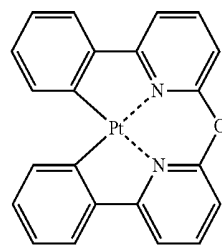
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PD42



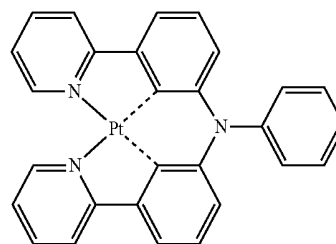
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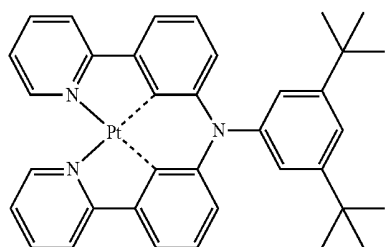


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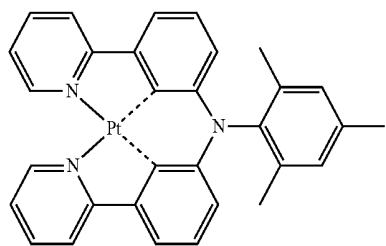
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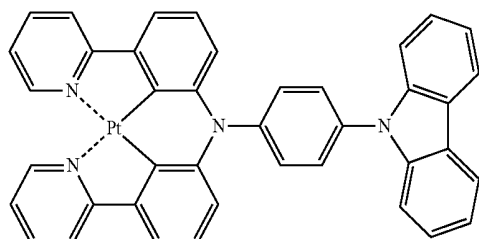
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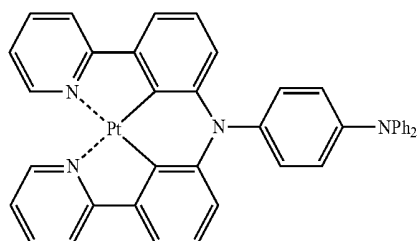
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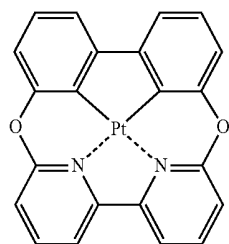
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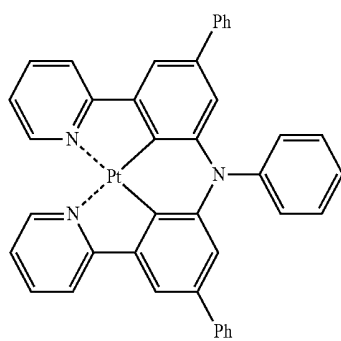
PD52



PD53

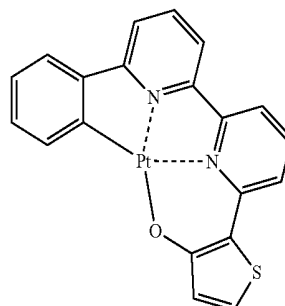


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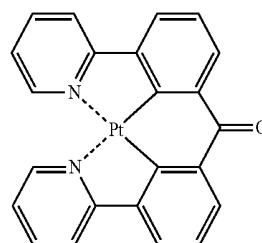


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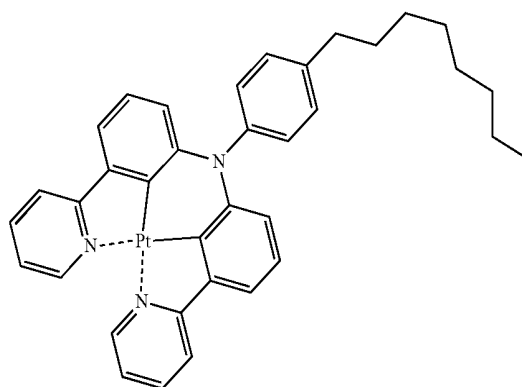
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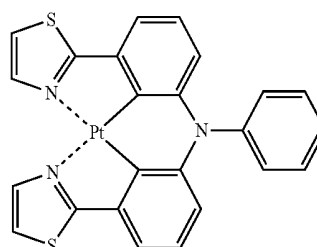
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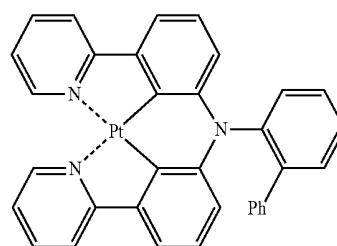
PD57



PD58

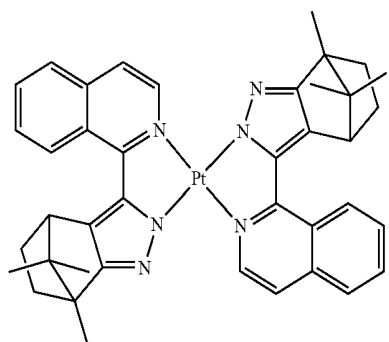


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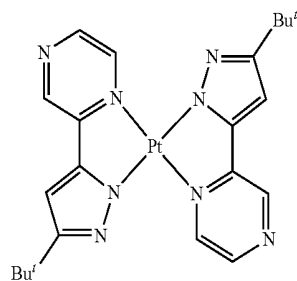
PD60

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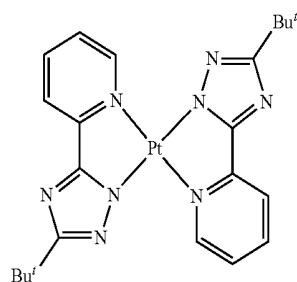
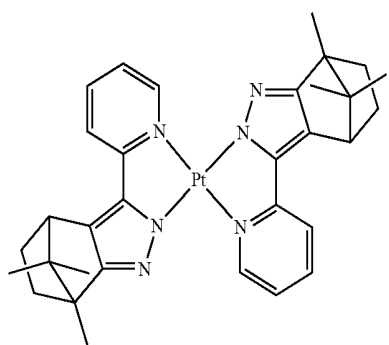
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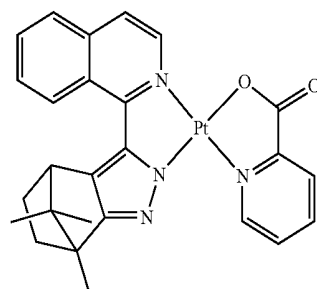
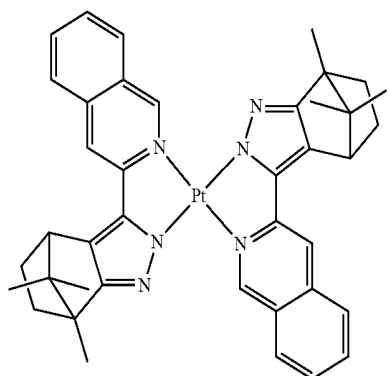
PD66

PD62



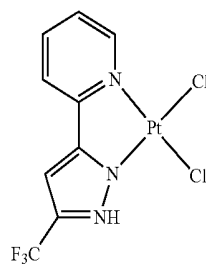
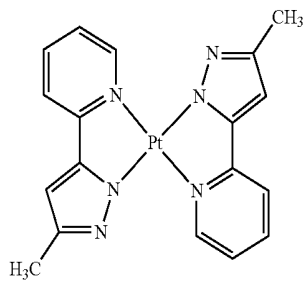
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PD63



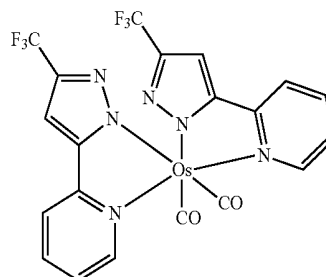
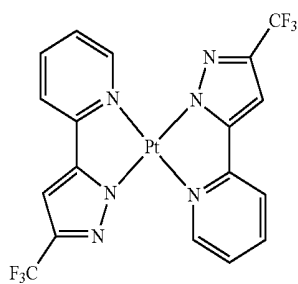
PD68

PD64



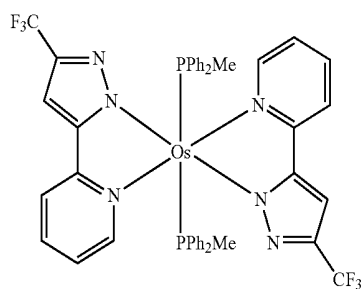
PD69

PD65



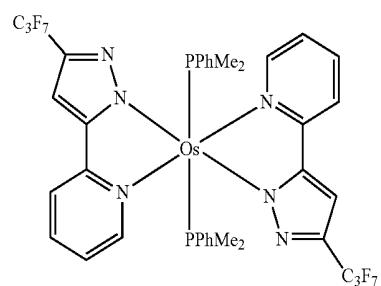
PD70

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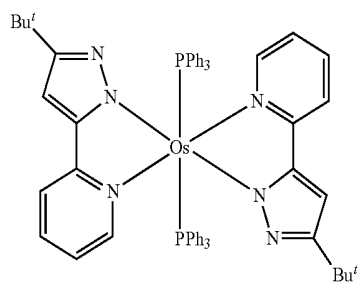


PD71

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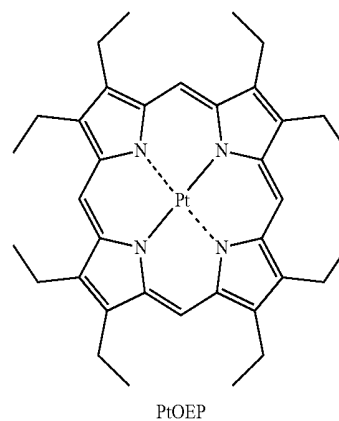


PD74

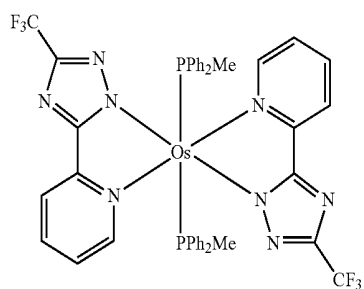


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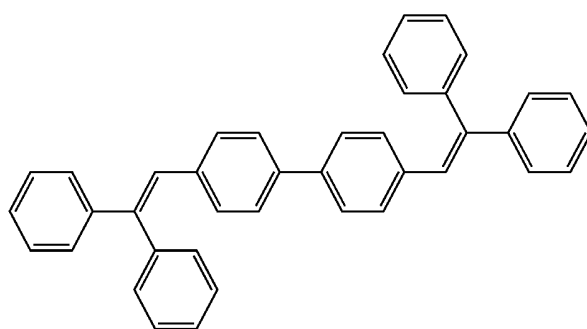
[0126] According to an embodiment, the phosphorescent dopant may include PtOEP:



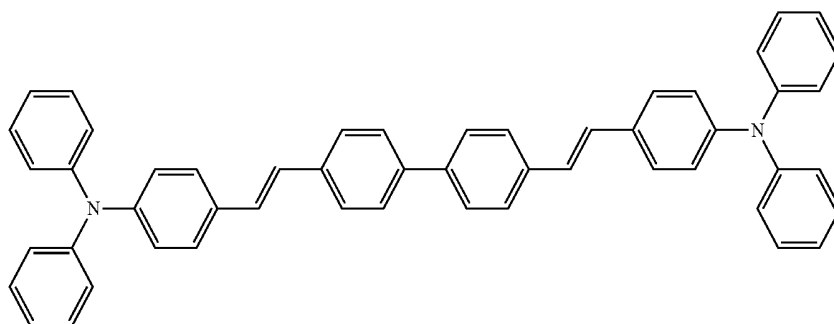
PD73

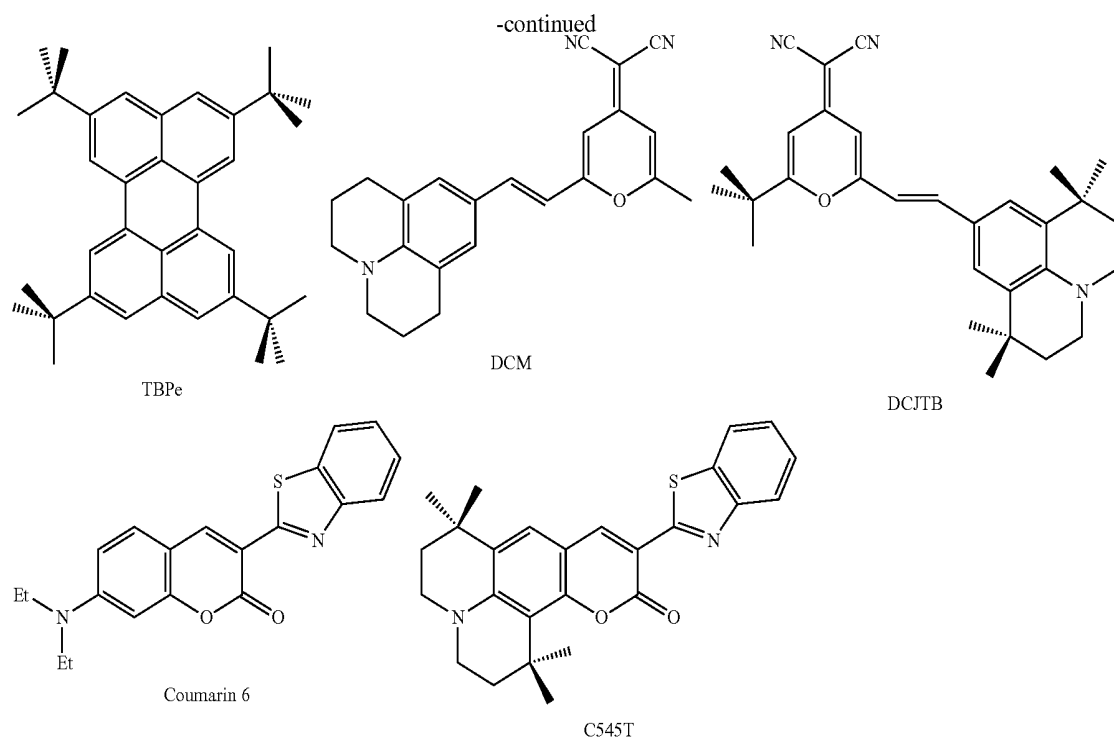


[0127] The fluorescent dopant may include at least one selected from DPAVB_i, BDAVB_i, TBPe, DCM, DUTB, Coumarin 6, and C545T.

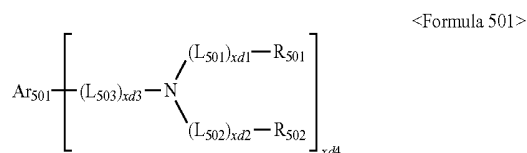


DPVBi

DPAVB_i



[0128] According to an embodiment, the fluorescent dopant may include a group represented by Formula 501 below:



[0129] wherein in Formula 501,

[0130] Ar₅₀₁ may be selected from

[0131] a naphthalene, a heptalene, a fluorene, a spiro-fluorene, a benzofluorene, a dibenzofluorene, a phenylene, a phenanthrene, an anthracene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a naphthacene, a picene, a perylene, a pentaphene, and an indenoanthracene; and

[0132] a naphthalene, a heptalene, a fluorene, a spiro-fluorene, a benzofluorene, a dibenzofluorene, a phenylene, a phenanthrene, an anthracene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a naphthacene, a picene, a perylene, a pentaphene, and an indenoanthracene, each substituted with at least one selected from a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₂-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₂-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₂-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, monovalent non-aromatic condensed heteropolycyclic group, and —Si(Q₅₀₁)(Q₅₀₂)(Q₅₀₃) (Q₅₀₁ to Q₅₀₃ may be each independently selected from a hydrogen, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₆-C₆₀ aryl group, and a C₂-C₆₀ heteroaryl group);

[0133] descriptions of L₅₀₁ to L₅₀₃ may be the same as the description provided herein in connection with L₃₀₁;

[0134] R₅₀₁ and R₅₀₂ may be each independently selected from

[0135] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

[0136] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a Spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

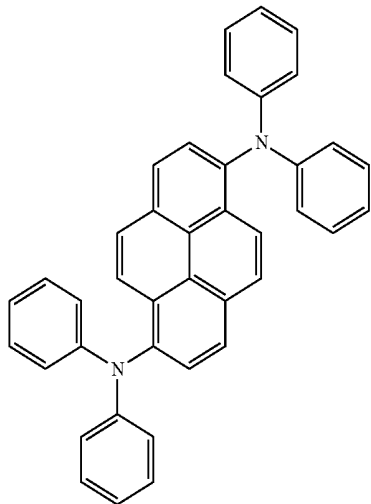
[0137] x_{d1} to x_{d3} may be each independently selected from 0, 1, 2, and 3; and

[0138] x_{b4} may be selected from 1, 2, 3, and 4.

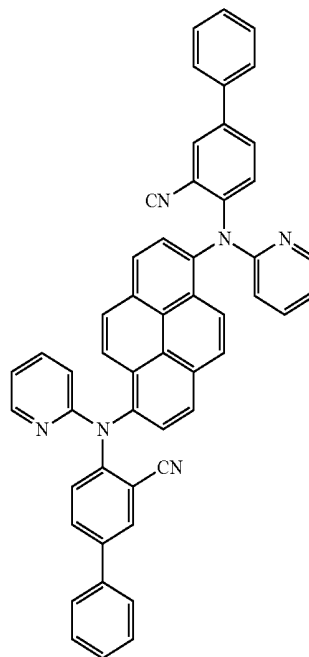
[0139] The fluorescent host may include at least one selected from Compounds FD1 to FD8.

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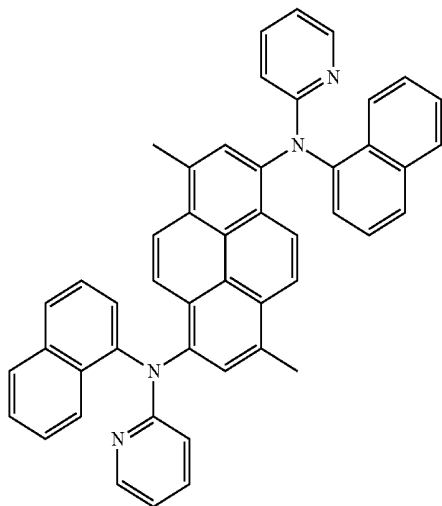
FD1



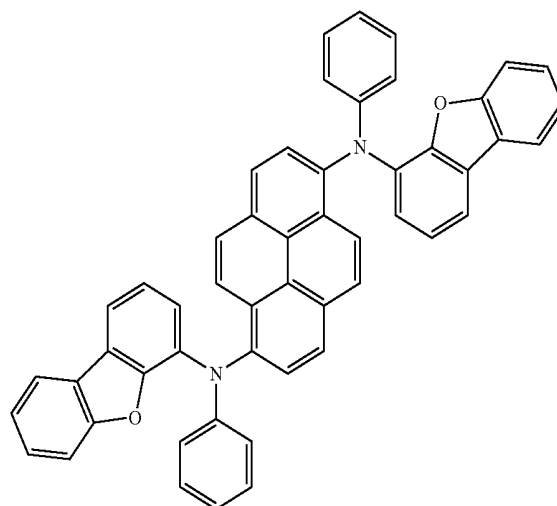
FD4



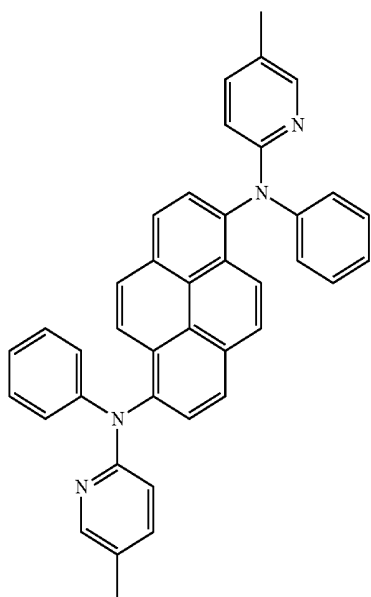
FD2



FD5

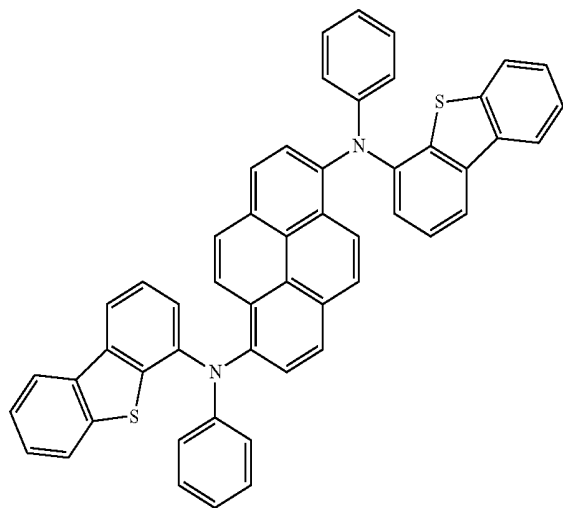


FD3

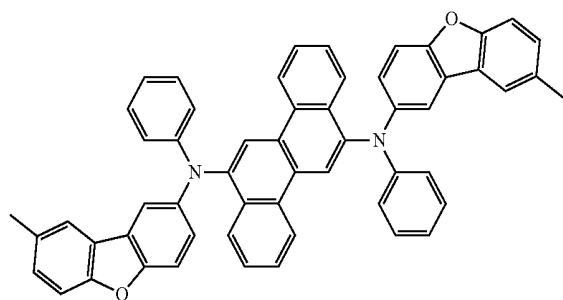


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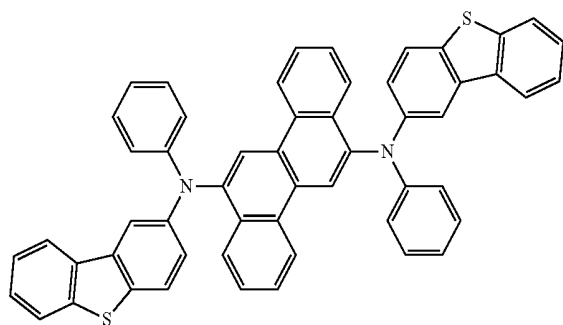
FD6



FD7



FD8



[0140] An amount of the dopant in the emission layer may be, for example, in a range of about 0.01 to about 15 parts by weight based on 100 parts by weight of the host.

[0141] 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. Maintaining the thickness of the emission layer within this range may help provide excellent light-emission characteristics without a substantial increase in driving voltage.

[0142] Then, an electron transport region may be disposed on the emission layer.

[0143] The electron transport region may include, for example, at least one selected from a hole blocking layer, an electron transport layer (ETL), and an electron injection layer.

[0144] For example, the electron transport region may have a structure of electron transport layer/electron injection

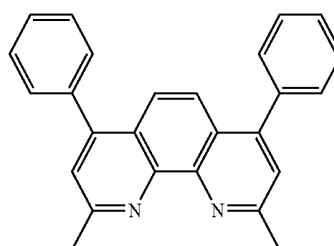
layer or a structure of hole blocking layer/electron transport layer/electron injection layer, wherein layers of each structure are, for example, sequentially stacked from the emission layer in the stated order.

[0145] According to an embodiment, the organic layer 150 of the organic light-emitting device may include an electron transport region disposed between the emission layer and the second electrode 190.

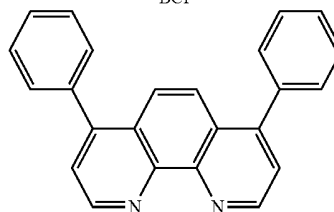
[0146] The electron transport region may include a hole blocking layer. The hole blocking layer may be formed, when the emission layer includes a phosphorescent dopant, to prevent diffusion of excitons or holes into an electron transport layer.

[0147] When the electron transport region includes a hole blocking layer, the hole blocking layer may be formed on the emission layer using various methods, such as vacuum deposition, spin coating casting, a Langmuir-Blodgett (LB) method, ink-jet printing, laser-printing, or laser-induced thermal imaging. When the hole blocking layer is formed by vacuum deposition or spin coating, deposition and coating conditions for the hole blocking layer may be determined by referring to the deposition and coating conditions for the hole injection layer.

[0148] The hole blocking layer may include, for example, at least one selected from BCP and Bphen.



BCP



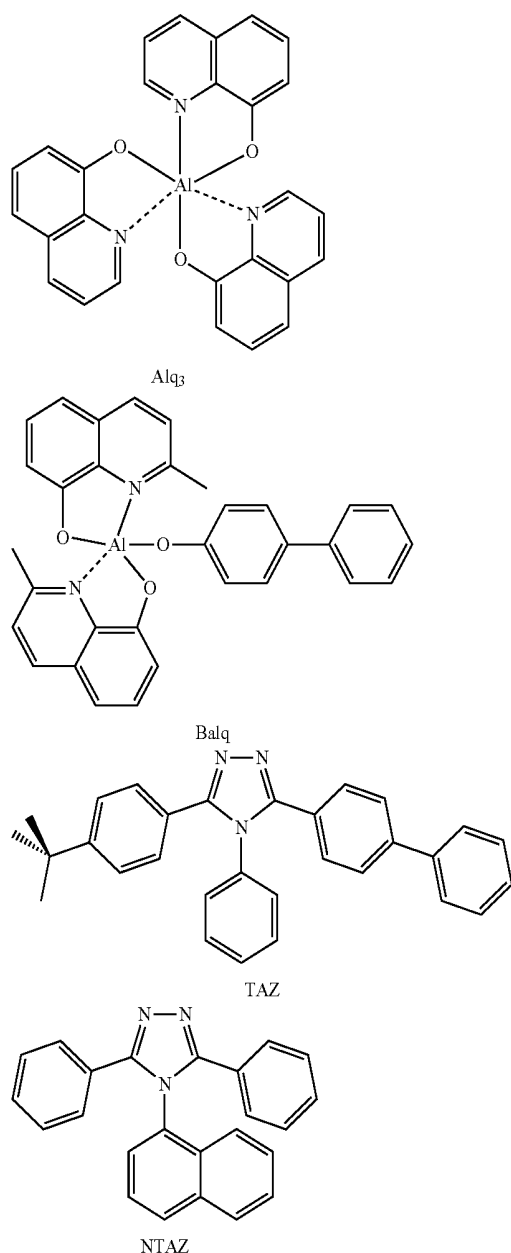
Bphen

[0149] A thickness of the hole blocking layer may be in a range of about 20 Å to about 1,000 Å, for example, about 30 Å to about 300 Å. Maintaining the thickness of the hole blocking layer within these ranges may help provide the hole blocking layer excellent hole blocking characteristics without a substantial increase in driving voltage.

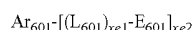
[0150] The electron transport region may include an electron transport layer. The electron transport layer may be formed on the emission layer or the hole blocking layer using various methods, such as vacuum deposition, spin coating casting, a LB method, ink-jet printing, laser-printing, or laser-induced thermal imaging. When an electron transport layer is formed by vacuum deposition or spin coating, deposition and coating conditions for the electron transport layer may be the same as the deposition and coating conditions for the hole injection layer.

[0151] According to an embodiment, the organic layer 150 of the organic light-emitting device includes an electron transport region disposed between the emission layer and the second electrode 190, and the electron transport region may include an electron transport layer. The electron transport layer may include a plurality of layers. For example, the electron transport layer may include a first electron transport layer and a second electron transport layer.

[0152] The electron transport layer may further include, in addition to an organometallic group, at least one selected from BCP, Bphen, Alq₃, Balq, TAZ, and NTAZ.



[0153] According to an embodiment, the electron transport layer may include at least one group selected from a group represented by Formula 601 and a group represented by Formula 602 illustrated below:



<Formula 601>

[0154] wherein in Formula 601,

[0155] Ar₆₀₁ may be selected from

[0156] a naphthalene, a heptalene, a fluorene, a spirofluorene, a benzofluorene, a dibenzofluorene, a phenalene, a phenanthrene, an anthracene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a naphthacene, a picene, a perylene, a pentaphene, and an indenoanthracene;

[0157] a naphthalene, a heptalene, a fluorene, a spirofluorene, a benzofluorene, a dibenzofluorene, a phenalene, a phenanthrene, an anthracene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a naphthacene, a picene, a perylene, a pentaphene, and an indenoanthracene, each substituted with at least one selected from a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₃-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₃-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₂-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, monovalent non-aromatic condensed heteropolycyclic group, and —Si(Q₃₀₁)(Q₃₀₂)(Q₃₀₃) (Q₃₀₁ to Q₃₀₃ may be each independently selected from a hydrogen, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₆-C₆₀ aryl group, and a C₂-C₆₀ heteroaryl group);

[0158] descriptions of L₆₀₁ may be the same as the description provided herein in connection with L₃₀₁;

[0159] E₆₀₁ may be selected from

[0160] a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isooxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a furinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group; and

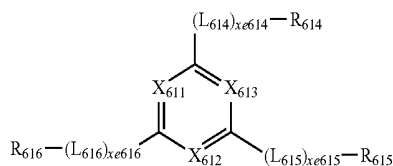
[0161] a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isooxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a furinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl

group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, each substituted with at least one selected from a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isooxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a furinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group;

[0162] xe1 may be selected from 0, 1, 2, and 3; and

[0163] xe2 may be selected from 1, 2, 3, and 4.

<Formula 602>



[0164] In Formula 602,

[0165] X₆₁₁ may be N or C—(L₆₁₁)_{xe611}—R₆₁₁, X₆₁₂ may be N or C—(L₆₁₂)_{xe612}—R₆₁₂, X₆₁₃ may be N or C—(L₆₁₃)_{xe613}—R₆₁₃, and at least one selected from X₆₁₁ to X₆₁₃ may be N; descriptions of L₆₁₁ to L₆₁₆ may be the same as the description provided herein in connection with L₃₀₁;

[0166] R₆₁₁ and R₆₁₆ may be each independently selected from

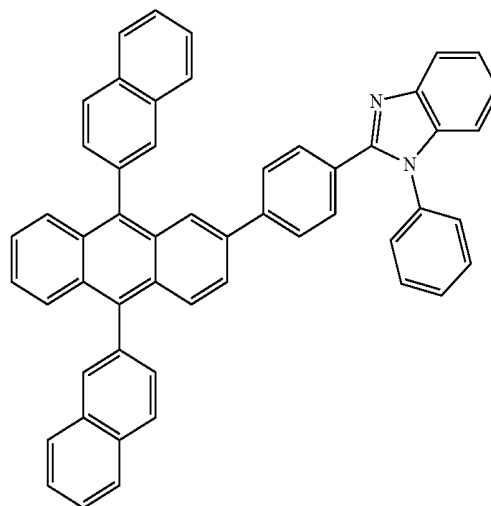
[0167] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

[0168] a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, each substituted with at least one selected from a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C₁-C₂₀ alkyl group, a C₁-C₂₀ alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

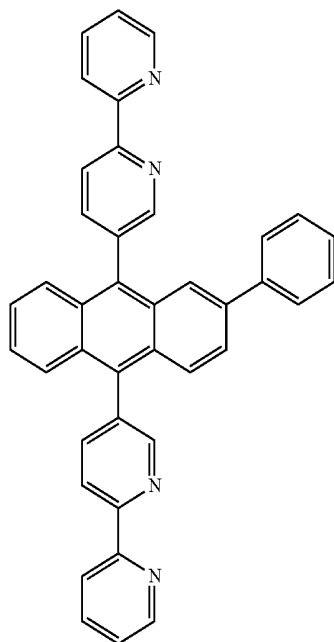
[0169] xe611 to xe616 may be each independently selected from 0, 1, 2, and 3.

[0170] The group represented by Formula 601 and the group represented by Formula 602 may each be selected from Compounds ET1 to ET15 illustrated below.

ET1

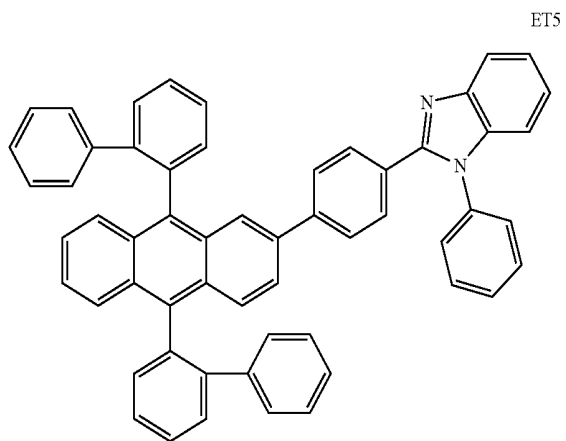


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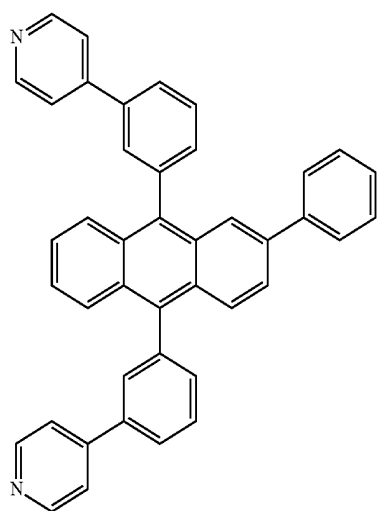


ET2

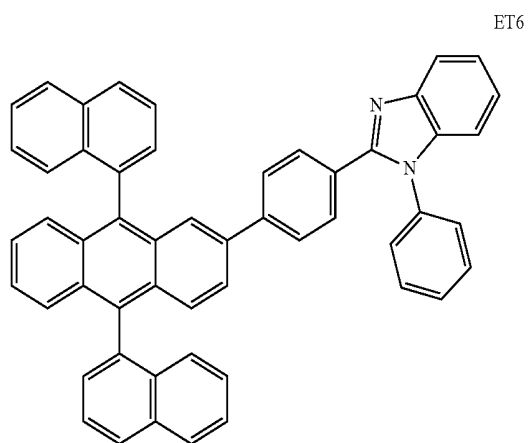
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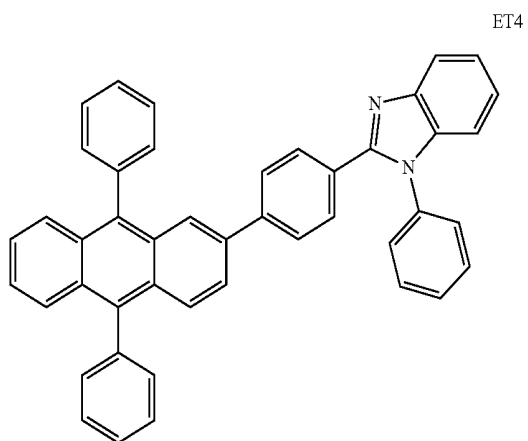
ET5



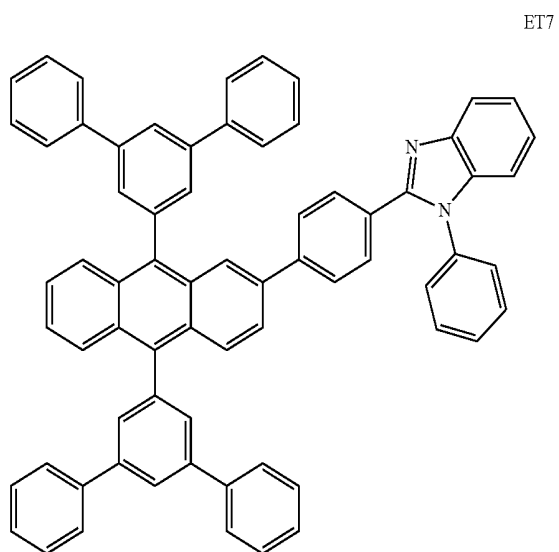
ET3



ET6



ET4



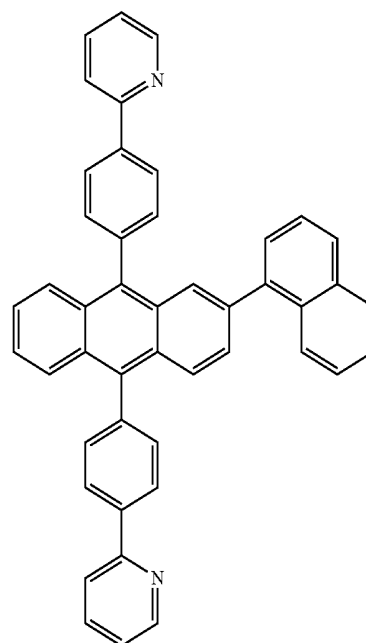
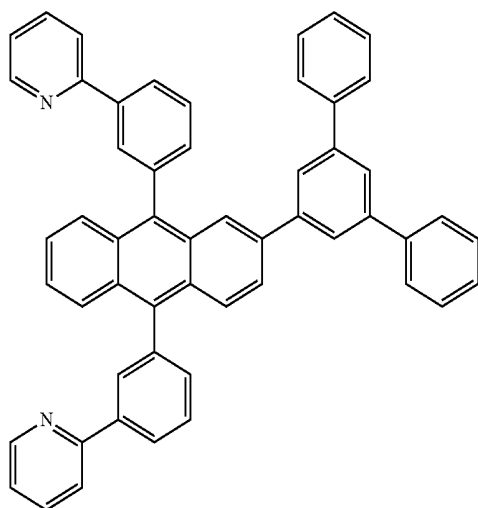
ET7

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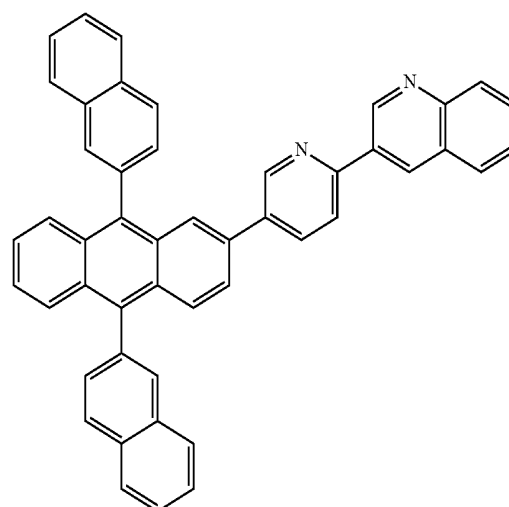
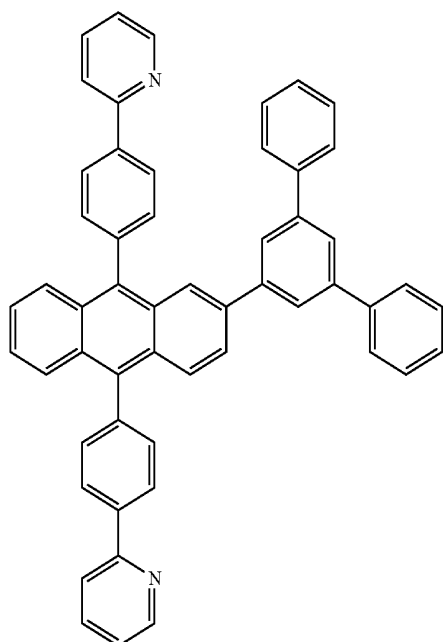
ET10

ET8

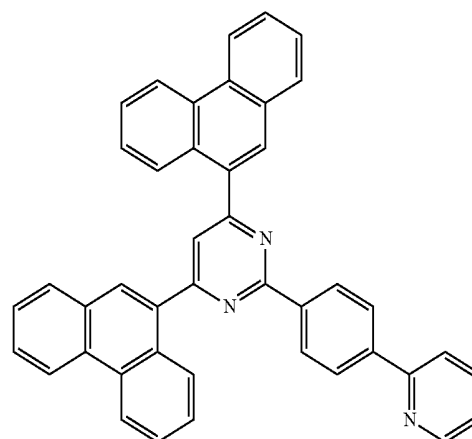


ET11

ET9

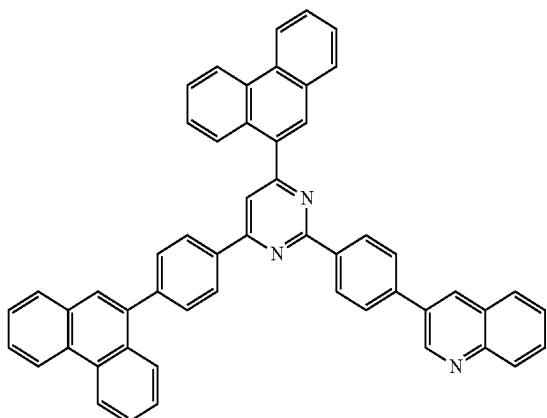


ET12

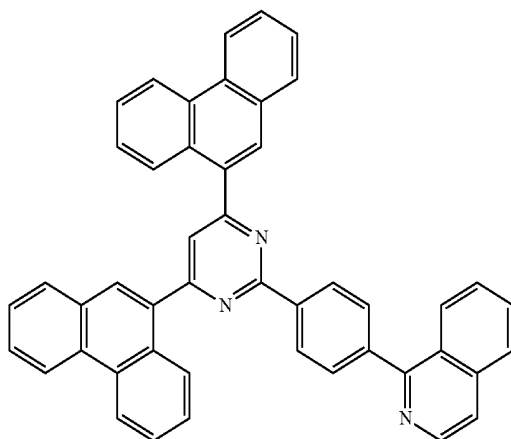


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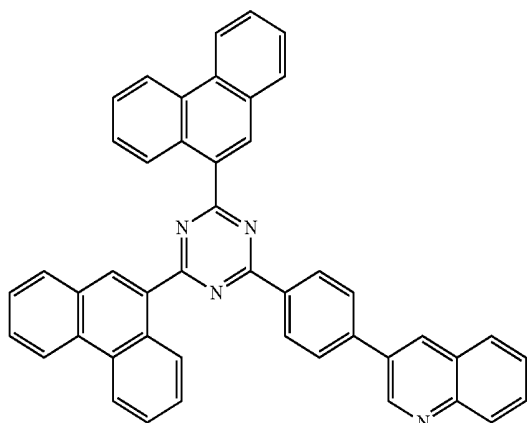
ET13



ET14



ET15

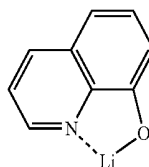


[0171] A thickness of the electron transport layer may be in a range of about 100 Å to about 1,000 Å, for example, about 150 Å to about 500 Å. Maintaining the thickness of the electron transport layer within the range described above may help provide the electron transport layer satisfactory electron transport characteristics without a substantial increase in driving voltage.

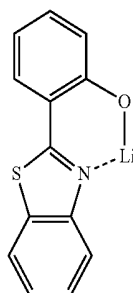
[0172] The electron transport layer may further include, in addition to the materials described above, a metal-containing material.

[0173] 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.

ET-D1



ET-D2



[0174] The electron transport region may include an electron injection layer that allows electrons to be easily provided from the second electrode 190.

[0175] The electron injection layer may be formed on the electron transport layer using various methods, such as vacuum deposition, spin coating casting, a LB method, ink-jet printing, laser-printing, or laser-induced thermal imaging. When an electron injection layer is formed by vacuum deposition or spin coating, deposition and coating conditions for the electron injection layer may be the same as those for the hole injection layer.

[0176] The electron injection layer may include at least one selected from, LiF, NaCl, CsF, Li₂O, BaO, and LiQ.

[0177] 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. Maintaining the thickness of the electron injection layer within the range described above may help provide the electron injection layer satisfactory electron injection characteristics without a substantial increase in driving voltage.

[0178] The second electrode 190 may be 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 a material for the second electrode 190 may be metal, an alloy, an electrically conductive compound, and a mixture thereof, each having a low work function. Detailed examples of the second electrode 190 are lithium (Li), magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), or magnesium-silver (Mg—Ag). According to an embodiment, the material for forming the second electrode 190 may be ITO or IZO. The second electrode 190 may be a reflective electrode, a semi-transmissive electrode, or a transmissive electrode.

[0179] In addition, when an organic light-emitting device according to an embodiment includes an organic layer as described above, the organic layer may be formed using a deposition method or a wet method in which a compound according to an embodiment prepared in the solution form is used for coating.

[0180] An organic light-emitting device according to an embodiment may be used in various flat panel display apparatuses, such as a passive matrix organic light-emitting display apparatus or an active matrix organic light-emitting display apparatus. In particular, when the organic light-emitting device is included in an active matrix organic light-emitting display apparatus, a first electrode disposed on a substrate acts as a pixel and may be electrically connected to a source or drain electrode of a thin film transistor. In addition, the organic light-emitting device may be included in a flat panel display apparatus that emits light in opposite directions.

[0181] FIG. 2 illustrates a schematic cross-sectional view of an organic light-emitting device according to an embodiment. Referring to FIG. 2, a first electrode may contact a layer formed of only a low work function metal compound, and the layer formed of only a low work function metal compound may contact a hole transport layer.

[0182] Examples of low work function metal compounds are described above. A low work function metal compound may lower a hole injection barrier due to a dipole moment thereof. However, in a case in which the metal compound is dissociated, a low work function metal compound may increase an energy barrier. In this regard, the low work function metal compound having a strong binding force is required.

[0183] FIG. 3 illustrates a schematic cross-sectional view of an organic light-emitting device according to an embodiment. Referring to FIG. 3, a first electrode may contact a layer formed of a low work function metal compound and a hole injection material, and the layer formed of a low work function metal compound and a hole injection material may contact a hole transport layer.

[0184] Examples of low work function metal compounds are described above. The layer is formed of a low work function metal compound and a hole injection material, the metal compound of the layer may take electrons from a hole injection material, and have a p-doping characteristic.

[0185] Heretofore, the organic light-emitting device was described by referring, for example, to FIGS. 1 to 3.

[0186] Hereinafter, definitions of substituents used herein will be presented (the number of carbon numbers used to restrict a substituent is not limited, and does not limit properties of the substituent, and unless defined otherwise, the definition of the substituent is consistent with a general definition thereof).

[0187] A C_1 - C_{60} alkyl group used herein refers to a linear or branched aliphatic hydrocarbon monovalent group having 1 to 60 carbon atoms, and detailed examples thereof are 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. A C_1 - C_{60} alkenylene group used herein refers to a divalent group having the same structure as the C_1 - C_{60} alkyl group.

[0188] A C_1 - C_{60} alkoxy group used herein refers to a monovalent group represented by $-OA_{101}$ (wherein A_{101} is the C_1 - C_{60} alkyl group), and detailed examples thereof are a methoxy group, an ethoxy group, and an isopropoxy group.

[0189] A C_2 - C_{60} alkenyl group used herein refers to a hydrocarbon group having at least one carbon double bond in the middle or terminal of the C_2 - C_{60} alkyl group, and detailed examples thereof are an ethenyl group, a propenyl

group, and a butenyl group. A C_2 - C_{60} alkenylene group used herein refers to a divalent group having the same structure as the C_2 - C_{60} alkenyl group.

[0190] A C_2 - C_{60} alkynyl group used herein refers to a hydrocarbon group having one carbon triple bond in the middle or terminal of the C_2 - C_{60} alkyl group, and detailed examples thereof are an ethynyl group, and a propynyl group. A C_2 - C_{60} alkynylene group used herein refers to a divalent group having the same structure as the C_2 - C_{60} alkynyl group.

[0191] A C_3 - C_{10} cycloalkyl group used herein refers to a monovalent hydrocarbon monocyclic group having 3 to 10 carbon atoms, and detailed examples thereof are a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. A C_3 - C_{10} cycloalkylene group used herein refers to a divalent group having the same structure as the C_3 - C_{10} cycloalkyl group.

[0192] A C_2 - C_{10} heterocycloalkyl group used herein refers to a monovalent monocyclic group having at least one hetero atom selected from N, O, P, and S as a ring-forming atom and 2 to 10 carbon atoms, and detailed examples thereof are a tetrahydrofuranyl group, and a tetrahydrothiophenyl group. A C_2 - C_{10} heterocycloalkylene group used herein refers to a divalent group having the same structure as the C_2 - C_{10} heterocycloalkyl group.

[0193] A C_3 - C_{10} cycloalkenyl group used herein refers to a monovalent monocyclic group that has 3 to 10 carbon atoms and at least one double bond in the ring thereof and does not have aromaticity, and detailed examples thereof are a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. A C_3 - C_{10} cycloalkenylene group used herein refers to a divalent group having the same structure as the C_3 - C_{10} cycloalkenyl group.

[0194] A C_2 - C_{10} heterocycloalkenyl group used herein refers to a monovalent monocyclic group that has at least one hetero atom selected from N, O, P, and S as a ring-forming atom, 2 to 10 carbon atoms, and at least one double bond in its ring. Detailed examples of the C_2 - C_{10} heterocycloalkenyl group are a 2,3-dihydrofuranyl group and a 2,3-dihydrothiophenyl group. A C_2 - C_{10} heterocycloalkenylene group used herein refers to a divalent group having the same structure as the C_2 - C_{10} heterocycloalkenyl group.

[0195] A C_6 - C_{60} aryl group used herein refers to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms, and a C_6 - C_{60} arylene group used herein refers to a divalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms. Detailed examples of the C_6 - C_{60} aryl group are a phenyl group, a naphthyl group, an anthracenyl group, a phenanthrenyl group, a pyrenyl group, and a chrysenyl group. When the C_6 - C_{60} aryl group and the C_6 - C_{60} arylene group each include two or more rings, the rings may be fused to each other.

[0196] A C_2 - C_{60} heteroaryl group used herein refers to a monovalent group having a carbocyclic aromatic system that has at least one hetero atom selected from N, O, P, and S as a ring-forming atom, and 2 to 60 carbon atoms. A C_2 - C_{60} heteroarylene group used herein refers to a divalent group having a carbocyclic aromatic system that has at least one hetero atom selected from N, O, P, and S as a ring-forming atom, and 2 to 60 carbon atoms. Examples of the C_2 - C_{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 C₂-C₆₀ heteroaryl group and the C₂-C₆₀ heteroarylene group each include two or more rings, the rings may be fused to each other.

[0197] A C₆-C₆₀ aryloxy group used herein indicates —OA₁₀₂ (wherein A₁₀₂ is the C₆-C₆₀ aryl group), and a C₆-C₆₀ arylthio group indicates —SA₁₀₃ (wherein A₁₀₃ is the C₆-C₆₀ aryl group).

[0198] A monovalent non-aromatic condensed polycyclic group used herein refers to a monovalent group (for example, having 8 to 60 carbon atoms) that has two or more rings condensed to each other, only carbon atoms as a ring forming atom, and non-aromaticity in the entire molecular structure. A detailed example of the monovalent non-aromatic condensed polycyclic group is a fluorenyl group. A 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.

[0199] A monovalent non-aromatic condensed heteropolycyclic group used herein refers to a monovalent group (for example, having 2 to 60 carbon atoms) that has two or more rings condensed to each other, has a heteroatom selected from N, O, P, and S, other than carbon atoms, as a ring forming atom, and has non-aromaticity in the entire molecular structure. An example of the monovalent non-aromatic condensed heteropolycyclic group is a carbazolyl group. A divalent non-aromatic condensed heteropolycyclic group used herein refers to a divalent group having the same structure as the monovalent non-aromatic condensed heteropolycyclic group.

[0200] In the present specification, at least one substituent selected from the substituted C₃-C₁₀ cycloalkylene group, the substituted C₂-C₁₀ heterocycloalkylene group, the substituted C₃-C₁₀ cycloalkenylene group, the substituted C₂-C₁₀ heterocycloalkenylene group, the substituted C₆-C₆₀ arylene group, the substituted C₂-C₆₀ heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, the substituted divalent non-aromatic condensed heteropolycyclic group, the substituted C₁-C₆₀ alkyl group, the substituted C₂-C₆₀ alkenyl group, the substituted C₂-C₆₀ alkynyl group, the substituted C₁-C₆₀ alkoxy group, the substituted C₃-C₁₀ cycloalkyl group, the substituted C₂-C₁₀ heterocycloalkyl group, the substituted C₃-C₁₀ cycloalkenyl group, the substituted C₂-C₁₀ heterocycloalkenyl group, the substituted C₆-C₆₀ aryl group, the substituted C₆-C₆₀ aryloxy group, the substituted C₆-C₆₀ arylthio group, the substituted C₂-C₆₀ heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from

[0201] a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group;

[0202] a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, and a C₁-C₆₀ alkoxy group, each substituted with at least one selected from a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof,

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

[0203] a C₃-C₁₀ cycloalkyl group, a C₂-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₂-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₂-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

[0204] a C₃-C₁₀ cycloalkyl group, a C₂-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₂-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₂-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₂-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₂-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₆-C₆₀ aryloxy group, a C₆-C₆₀ arylthio group, a C₂-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —N(Q₂₁)(Q₂₂), —Si(Q₂₃)(Q₂₄)(Q₂₅) and —B(Q₂₆)(Q₂₇); and

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

[0205] Q₁ to Q₇, Q₁₁ to Q₁₇, Q₂₁ to Q₂₇, and Q₃₁ to Q₃₇ may be each independently selected from a hydrogen, a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C₁-C₆₀ alkyl group, a C₂-C₆₀ alkenyl group, a C₂-C₆₀ alkynyl group, a C₁-C₆₀ alkoxy group, a C₃-C₁₀ cycloalkyl group, a C₂-C₁₀ heterocycloalkyl group, a C₃-C₁₀ cycloalkenyl group, a C₂-C₁₀ heterocycloalkenyl group, a C₆-C₆₀ aryl group, a C₂-C₆₀ heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group.

[0206] For example, at least one substituent selected from the substituted C₃-C₁₀ cycloalkylene group, the substituted C₂-C₁₀ heterocycloalkylene group, the substituted C₃-C₁₀ cycloalkenylene group, the substituted C₂-C₁₀ heterocycloalkenylene group, the substituted C₆-C₆₀ arylene group, the substituted C₂-C₆₀ heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, the substituted divalent non-aromatic condensed heteropolycyclic group, the substituted C₁-C₆₀ alkyl group, the substituted C₂-C₆₀ alkenyl group, the substituted C₂-C₆₀ alkynyl group, the substituted C₁-C₆₀ alkoxy group, the substituted C₃-C₁₀ cycloalkyl group, the substituted C₂-C₁₀ heterocycloalkyl

group, the substituted C_3 - C_{10} cycloalkenyl group, the substituted C_2 - C_{10} heterocycloalkenyl group, the substituted C_6 - C_{60} aryl group, the substituted C_6 - C_{60} aryloxy group, the substituted C_6 - C_{60} arylthio group, the substituted C_2 - C_{60} heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from

[0207] a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60} alkynyl group, and a C_1 - C_{60} alkoxy group;

[0208] a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60} alkynyl group, and a C_1 - C_{60} alkoxy group, each substituted with at least one selected from a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isooxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a furinyl group, a quinolynyl group, an isoquinolynyl group, a benzoquinolynyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranlyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, —N(Q_{11})(Q_{12}), —Si(Q_{13})(Q_{14})(Q_{15}), and —B(Q_{16})(Q_{17});

[0209] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl

group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isooxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a furinyl group, a quinolynyl group, an isoquinolynyl group, a benzoquinolynyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranlyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group;

[0210] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isooxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a furinyl group, a quinolynyl group, an isoquinolynyl group, a benzoquinolynyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranlyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group, each substituted with at least one selected from a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60} alkynyl group, a C_1 - C_{60} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl

group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isooxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a furinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, $-\text{N}(\text{Q}_{21})(\text{Q}_{22})$, $-\text{Si}(\text{Q}_{23})(\text{Q}_{24})(\text{Q}_{25})$, and $-\text{B}(\text{Q}_{26})(\text{Q}_{27})$; and

$-\text{N}(\text{Q}_{31})(\text{Q}_{32})$, $-\text{Si}(\text{Q}_{33})(\text{Q}_{34})(\text{Q}_{35})$, and $-\text{B}(\text{Q}_{36})(\text{Q}_{37})$.

[0211] Q_1 to Q_7 , Q_{11} to Q_{17} , Q_{21} to Q_{27} , and Q_{31} to Q_{37} may be each independently selected from a hydrogen, a deuterium, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1 - C_{60} alkyl group, a C_2 - C_{60} alkenyl group, a C_2 - C_{60} alkynyl group, a C_1 - C_{60} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spirofluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isooxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a furinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzooxazolyl group, an isobenzooxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl

group, a thiadiazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group.

[0212] The following Example and Comparative Example are provided in order to highlight characteristics of one or more embodiments, but it will be understood that the Example and Comparative Example are not to be construed as limiting the scope of the embodiments, nor is the Comparative Example to be construed as being outside the scope of the embodiments. Further, it will be understood that the embodiments are not limited to the particular details described in the Example and Comparative Example.

Example 1

Insertion of RbI Hole Injection Layer

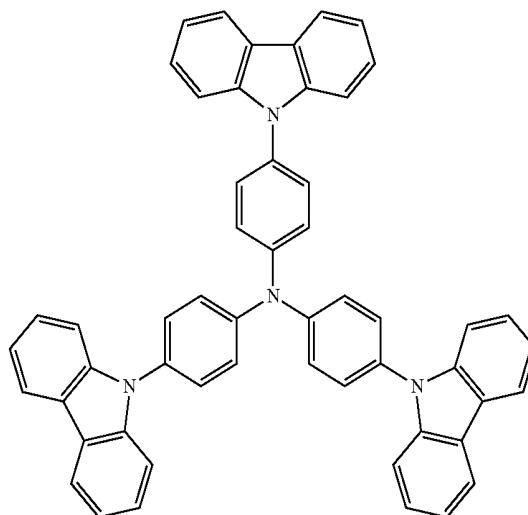
[0213] An ITO glass substrate was cut to a size of 50 mm×50 mm×0.5 mm and then, sequentially sonicated in acetone, isopropyl alcohol, and pure water, each for 15 minutes, and then, cleaned using UV ozone for 30 minutes.

[0214] Next, RbI was vacuum deposited on the ITO glass substrate to form a hole injection layer having a thickness of 5 Å.

[0215] TCTA was vacuum deposited on the layer to form a hole transport layer having a thickness of 600 Å.

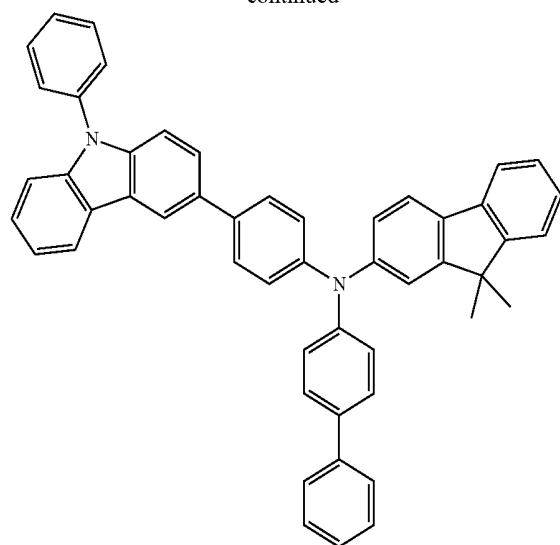
[0216] Then, H1 as a host and 5% of Ir(pq)2acac (300 Å) are vacuum deposited on the hole transport layer to form an emission layer having a thickness of 300 Å.

[0217] Next, Alq3 was vacuum deposited on the emission layer to form an electron transport layer having a thickness of 300 Å. 10 Å of LiF (electron injection layer) and 2000 Å of Al (cathode) were sequentially vacuum deposited on the electron transport layer, and an organic light-emitting device was manufactured.

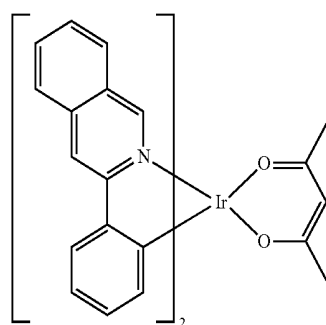
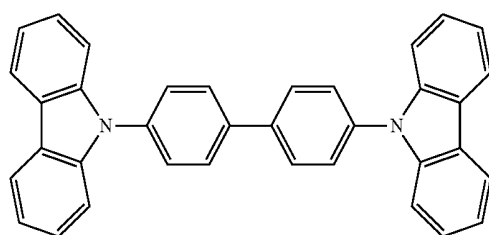


TCTA

-continued



HT1

Ir(pq)₂acac

CBP

Comparative Example 1 (Reference)

[0218] An organic light-emitting device was manufactured in the same manner as in Example 1, except that a RbI hole injection layer was not formed.

Comparison of Example and Comparative Example

[0219] The characteristics of the organic light-emitting device manufactured in Example according to an embodiment was compared to that of the organic light-emitting device in Comparative Example, and the results thereof are shown in Table 1 below.

TABLE 1

	Driving Voltage (V)	Efficiency (cd/A)
Example 1	4.6	9.2
Comparative Example 1	4.6	8.3

[0220] Referring to Table 1, the organic light-emitting device of Example 1 has better characteristics, e.g., efficiency, compared to the organic light-emitting device of Comparative Example 1.

[0221] FIG. 4 illustrates a graph of an efficiency of each of the devices of Example 1 and Comparative Example 1. FIG. 4 also shows that the organic light-emitting device of Example 1 has better characteristics, e.g., efficiency, compared to the organic light-emitting device of Comparative Example 1.

[0222] By way of summation and review, 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 may be 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, may be recombined in the emission layer to produce excitons, which may change from an excited state to a ground state, and light may be generated.

[0223] One or more exemplary embodiments include an organic light-emitting device that may have improved electric characteristics, e.g., provided by reducing an energy barrier between an electrode and an organic layer, and improving an interface characteristic of the organic layer.

[0224] As described above, according to the one or more of the above exemplary embodiments, the efficiency of an organic light-emitting device according to exemplary embodiment may be improved.

[0225] Example embodiments have been disclosed herein, and although specific terms are employed, they are used and are to be interpreted in a generic and descriptive sense only and not for purpose of limitation. In some instances, as would be apparent to one of skill in the art as of the filing of the present application, features, characteristics, and/or elements described in connection with a particular embodiment may be used singly or in combination with features, characteristics, and/or elements described in connection with other embodiments unless otherwise specifically indicated. Accordingly, it will be understood by those of skill in the art that various changes in form and details may be made without departing from the spirit and scope of the present invention as set forth in the following claims.

1.-20. (canceled)

21. An organic light-emitting device, comprising:

an anode;

a cathode facing the anode; and

an organic layer between the anode and the cathode and including an emission layer, the organic layer including:

a hole transport region between the anode and the emission layer, the hole transport region including a layer and

an electron transport region between the emission layer and the cathode, the electron transport region including an electron injection layer

wherein:

the organic layer includes a metal fluoride, and the organic layer directly contacts the anode.

22. The organic light-emitting device of claim **21**, wherein the organic layer includes a hole injection material.

23. The organic light-emitting device of claim **21**, wherein the metal has a work function in a range of more than 0 eV to 3 eV.

24. The organic light-emitting device of claim **21**, wherein the organic layer is a hole injection layer.

25. The organic light-emitting device of claim **21**, wherein the metal is an alkali metal.

26. The organic light-emitting device of claim **21**, wherein the metal is an alkaline earth metal.

27. The organic light-emitting device of claim **21**, wherein the metal is a lanthanide metal.

28. The organic light-emitting device of claim **21**, wherein the metal includes Li, Na, K, Rb, Cs, Be, Mg, Ca, Sr, Ba, Yb, or Sm.

29. The organic light-emitting device of claim **21**, wherein the metal fluoride includes LiF, NaF, KF, RbF, CsF, BeF₂, MgF₂, CaF₂, SrF₂, BaF₂, YbF, YbF₂, YbF₃, or SmF₃.

30. The organic light-emitting device of claim **21**, wherein the organic layer consists of metal fluoride.

31. The organic light-emitting device of claim **30**, wherein the organic layer has a thickness of 1 Å to 30 Å.

32. The organic light-emitting device of claim **21**, wherein the organic layer includes the metal fluoride and a hole injection material.

33. The organic light-emitting device of claim **32**, wherein the organic layer has a thickness of 1 Å to 100 Å.

34. A display apparatus, comprising:

an organic light-emitting device, including:

an anode;

a cathode facing the anode; and

an organic layer between the anode and the cathode, the organic layer including:

an emission layer,

a hole transport region between the anode and the emission layer, the hole transport region including a hole transport layer, and

an electron transport region between the emission layer and the cathode, the electron transport region including an electron injection layer,

wherein:

the organic layer includes a metal fluoride,

the organic layer directly contacts the anode, and

the anode of the organic light-emitting device is electrically connected to a source or drain electrode of a thin film transistor.

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专利名称(译)	有机发光装置和具有该有机发光装置的显示装置		
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申请(专利权)人(译)	三星DISPLAY CO. , LTD.		
当前申请(专利权)人(译)	三星DISPLAY CO. , LTD.		
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优先权	1020140122935 2014-09-16 KR		
外部链接	Espacenet USPTO		

摘要(译)

提供一种包括第一电极的有机发光装置;面向第一电极的第二电极;在第一电极和第二电极之间并包括发光层的有机层, 该有机层包括低功函数金属化合物。

SECOND ELECTRODE
EIL
ETL
EML
HTL
A LOW WORK FUNCTION METAL COMPOUND + A HOLE INJECTION MATERIAL
FIRST ELECTRODE