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ORGANIC LIGHT EMITTING DIODE
DISPLAY INCLUDING THE SAME****Publication Classification**(51) **Int. Cl.****H01L 51/00** (2006.01)**H01L 27/32** (2006.01)(52) **U.S. Cl.**CPC **H01L 51/0061** (2013.01); **H01L 27/3248**
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(57)

ABSTRACT

An organic light emitting diode includes: a first electrode and a second electrode that face each other; a middle layer on the first electrode; a hole transport layer on the middle layer; and an emission layer between the hole transport layer and the second electrode, wherein the middle layer includes a bipolar material formed by combining a first material including at least selected from a group 1 element, a group 2 element, a lanthanide metal, with a second material including a halogen element.

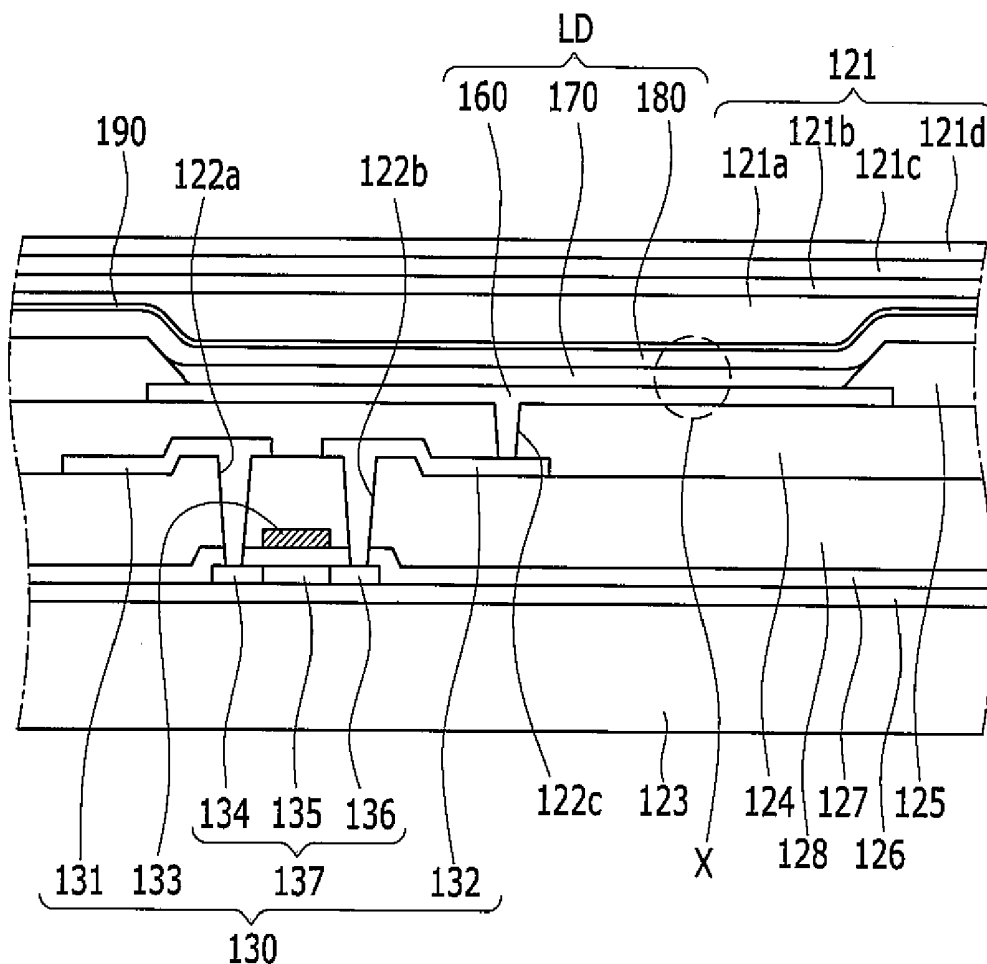


FIG. 1

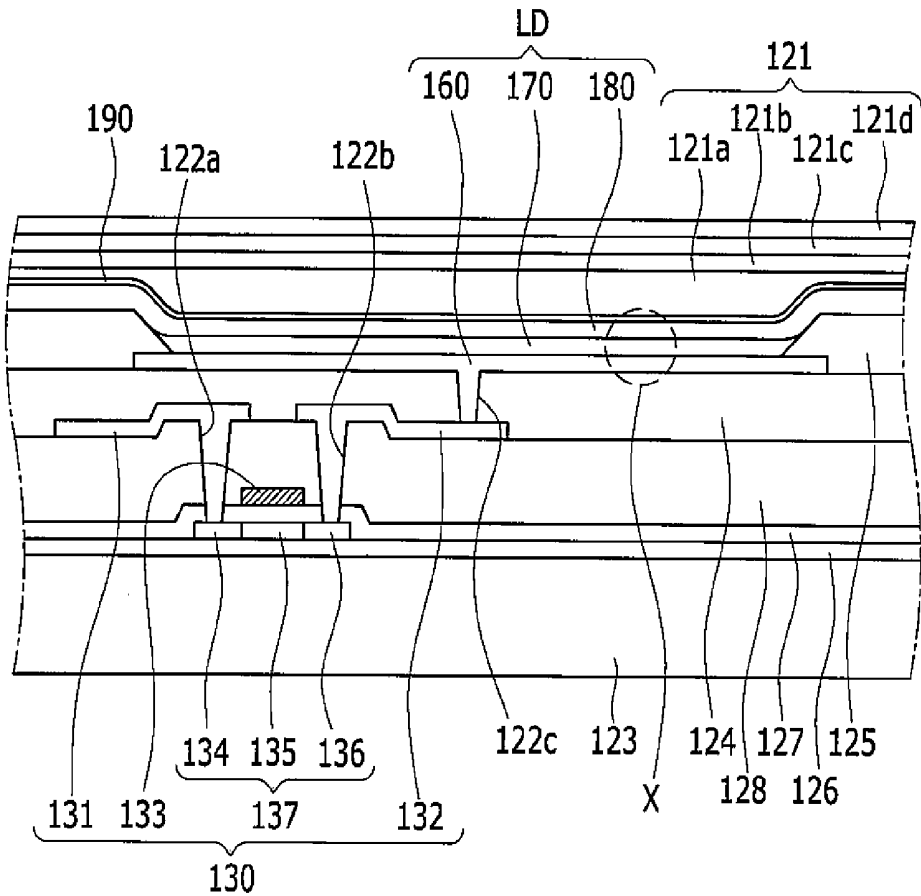


FIG. 2

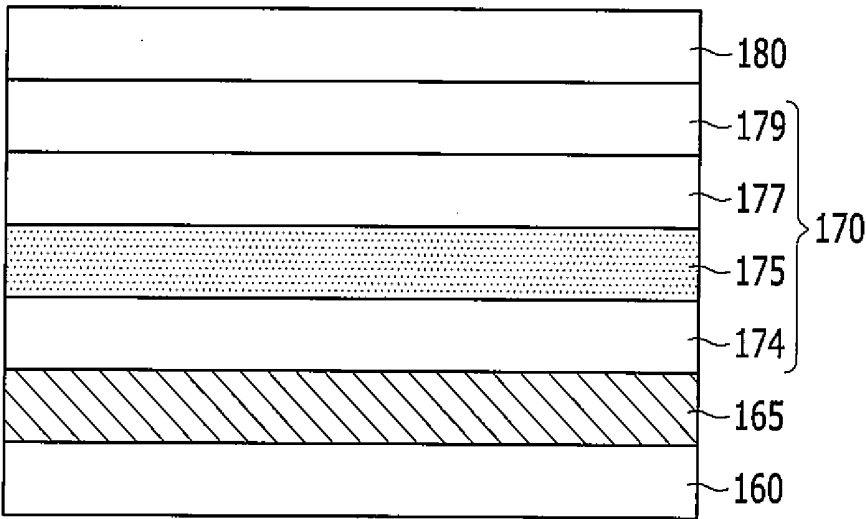


FIG. 3

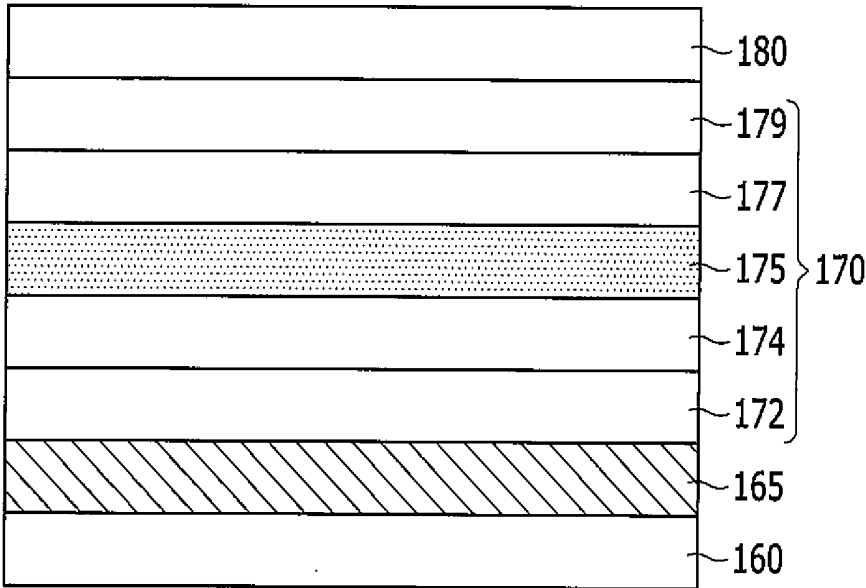
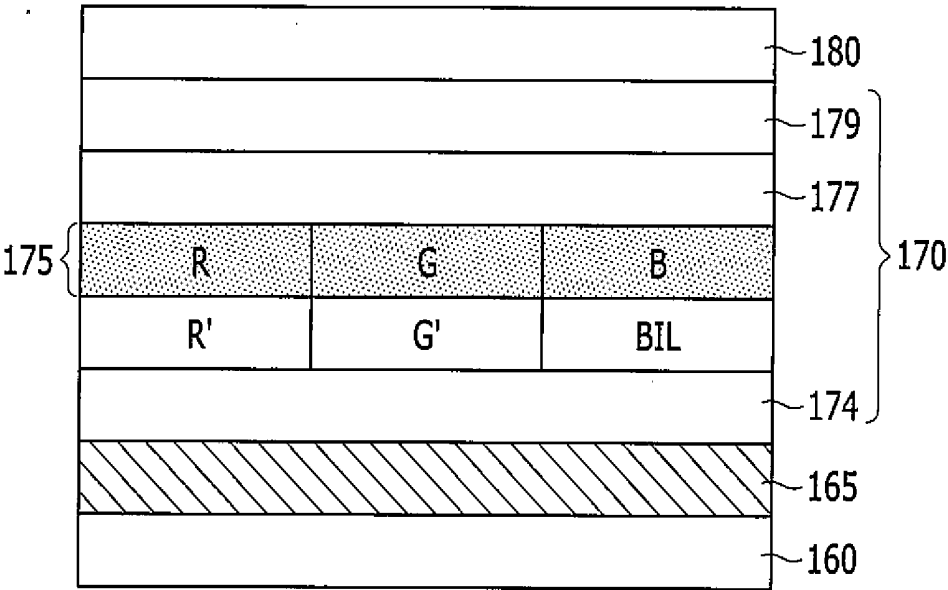


FIG. 4



**ORGANIC LIGHT EMITTING DIODE AND
ORGANIC LIGHT EMITTING DIODE
DISPLAY INCLUDING THE SAME**

**CROSS-REFERENCE TO RELATED
APPLICATION**

[0001] This application claims priority to and the benefit of Korean Patent Application No. 10-2015-0077495 filed in the Korean Intellectual Property Office on Jun. 1, 2015, the entire contents of which are incorporated herein by reference.

BACKGROUND

[0002] 1. Field

[0003] Embodiments of the present disclosure relate to an organic light emitting diode and an organic light emitting diode display including the same.

[0004] 2. Description of the Related Art

[0005] Recent trends toward lightweight and thin personal computers and televisions sets also require lightweight and thin display devices, and flat panel displays satisfying such requirements are being substituted for cathode ray tubes (CRTs). However, liquid crystal displays, which are a light receiving element, utilize a separate backlight and have limitations in response speed, viewing angle, and the like.

[0006] An organic light emitting device, which is a self-emitting display element having features of a wide viewing angle, excellent contrast, and a fast response time, has greatly attracted attention as a display device capable of overcoming the aforementioned limitations.

[0007] The organic light emitting display device includes an organic light emitting diode for light emission, and the organic light emitting diode forms excitons from a combination of electrons injected from one electrode and holes injected from another electrode in an emission layer, and the excitons emit energy such that light is emitted.

[0008] However, certain organic light emitting devices have problems of a high driving voltage, high light emission brightness, low luminance and light emission efficiency, and a short life span.

[0009] The above information disclosed in this Background section is only to enhance the understanding of the background of the present disclosure, and therefore it may contain information that does not form the prior art that is already known in this country to a person of ordinary skill in the art.

SUMMARY

[0010] Embodiments of the present disclosure have been made in an effort to provide an organic light emitting element that can provide smooth hole injection by adjusting a work function through halogenated treatment of a surface of an electrode of the organic light emitting element.

[0011] An organic light emitting diode according to an exemplary embodiment of the present disclosure includes: a first electrode and a second electrode that face each other; a middle layer provided on the first electrode; a hole transport layer provided on the middle layer; and an emission layer

provided between the hole transport layer and the second layer, wherein the middle layer includes a bipolar material formed by combining a first material including at least one selected from a group 1 element, a group 2 element, and a lanthanide metal, with a second material including a halogen element.

[0012] The middle layer may include at least one selected from an iodinated group 1 element, an iodinated group 2 element, an iodinated lanthanide metal, and an iodinated transition metal.

[0013] The middle layer may include at least one compound selected from LiI, NaI, KI, RbI, CsI, CuI, AgI, TlI, and CoI₂.

[0014] The thickness of the middle layer may be about 10 nm to about 20 nm.

[0015] The organic light emitting diode may further include a hole injection layer provided between the middle layer and the hole transport layer, wherein the hole injection layer and the hole transport layer may include an organic material.

[0016] A work function of the first electrode may be about 5.0 eV to about 7.0 eV.

[0017] A work function difference between the first electrode and the hole transport layer may be less than or equal to about 0.5 eV.

[0018] An organic light emitting diode display according to another exemplary embodiment of the present disclosure includes: a substrate; a thin film transistor provided on the substrate; and an organic light emitting diode coupled or connected to the thin film transistor, wherein the organic light emitting diode includes: a first electrode and a second electrode facing each other; a middle layer on the first electrode; a hole transport layer on the middle layer; and an emission layer on the hole transport layer, and the middle layer includes a bipolar material formed by combining a first material including at least one selected from a group 1 element, a group 2 element, and a lanthanide metal, with a second material including a halogen element.

[0019] The middle layer may include at least one selected from an iodinated group 1 element, an iodinated group 2 element, an iodinated lanthanide metal, and an iodinated transition metal.

[0020] A work function of the first electrode may be about 5.0 eV to about 7.0 eV.

[0021] A work function difference between the first electrode and the hole transport layer may be less than or equal to about 0.5 eV.

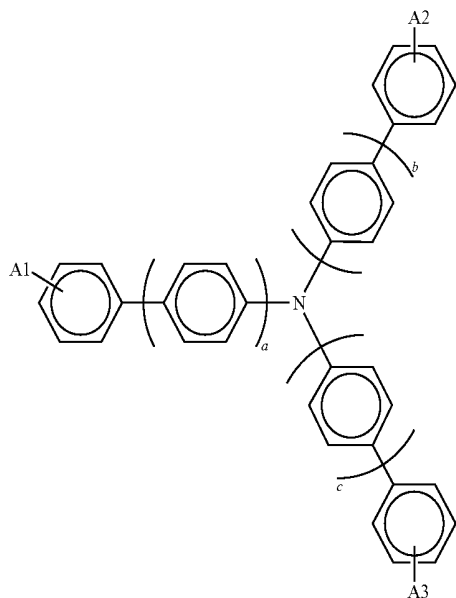
[0022] The organic light emitting diode may further include a hole injection layer between the middle layer and the hole transport layer, wherein the hole injection layer and the hole transport layer may each include an organic material.

[0023] The emission layer may include a red emission layer, a green emission layer, and a blue emission layer, and may further include an assistant layer at a lower end of the blue emission layer.

[0024] The emission layer may further include a red resonance assistant layer at a lower end of the red emission layer and a green resonance assistant layer at a lower end of the green emission layer.

[0025] The assistant layer may include a compound represented by Chemical Formula 1:

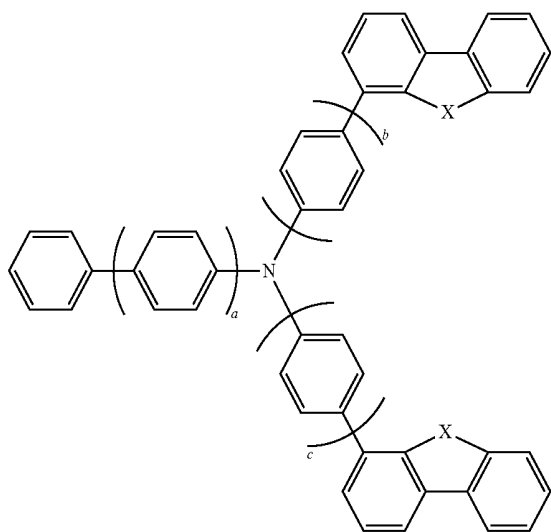
Chemical Formula 1



[0026] wherein in Chemical Formula 1, A1, A2, and A3 are each independently selected from an alkyl group, an aryl group, carbazole, dibenzothiophene, dibenzofuran (DBF), and biphenyl, and a, b, and c are each independently selected from positive numbers of zero to four.

[0027] The assistant layer may include a compound represented by Chemical Formula 2:

Chemical Formula 2



[0028] wherein, in Chemical Formula 2, a is selected from 0 to 3, and b and c are each independently selected from 0 to 3, X is selected from O, N, or S, and each X is the same as or different from each other.

[0029] According to an exemplary embodiment of the present disclosure, two (e.g., both) surfaces of an electrode are halogenated such that a work function of the surfaces can be adjusted, thereby improving hole injection characteristics.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] The accompanying drawings, together with the specification, illustrate embodiments of organic light emitting displays of the present disclosure, and, together with the description, serve to explain principles of embodiments of the organic light emitting displays.

[0031] FIG. 1 illustrates a cross-sectional view of an organic light emitting display according to an exemplary embodiment of the present disclosure.

[0032] FIG. 2 illustrates an enlarged cross-sectional view of an organic light emitting element of the organic light emitting display of FIG. 1.

[0033] FIG. 3 illustrates a cross-sectional view of an exemplary variation of a part of the organic light emitting element of FIG. 2 according to an exemplary variation.

[0034] FIG. 4 illustrates a cross-sectional view of an exemplary variation of a part of the organic light emitting element of FIG. 2.

DETAILED DESCRIPTION

[0035] Embodiments of the present disclosure will be described more fully hereinafter with reference to the accompanying drawings, in which exemplary embodiments of the disclosure are shown. As those skilled in the art would realize, the described embodiments may be modified in various different ways, all without departing from the spirit or scope of the present disclosure.

[0036] In the drawings, the thickness of layers, films, panels, regions, etc., may be exaggerated for clarity. Like reference numerals designate like elements throughout the specification. It will be understood that when an element such as a layer, film, region, or substrate is referred to as being "on," "coupled to," or "connected to" another element, the layer, film, region, or substrate can be directly on, directly coupled to, or directly connected to the other element or intervening elements may also be present. In contrast, when an element is referred to as being "directly on" another element, there are no intervening elements present. In addition, it will also be understood that when an element or layer is referred to as being "between" two elements or layers (e.g., an emission layer between a hole transport layer and a second layer), it can be the only element or layer between the two elements or layers, or one or more intervening elements or layers may also be present.

[0037] It will be understood that, although the terms "first," "second," "third," etc., may be used herein to describe various elements, components, regions, layers and/or sections (e.g., a first contact hole and a second contact hole), these elements, components, regions, layers and/or sections should not be limited by these terms. These terms are used to distinguish one element, component, region, layer or section from another element, component, region, layer or section (e.g., to distinguish one contact hole from another contact hole). Thus, a first element, component, region, layer or section described below could be termed a

second element, component, region, layer or section, without departing from the spirit and scope of the present invention.

[0038] Spatially relative terms, such as “beneath,” “below,” “lower,” “under,” “above,” “upper,” and the like, may be used herein for ease of explanation to describe one element or feature’s relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or in operation, in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as “below” or “beneath” or “under” other elements or features would then be oriented “above” the other elements or features. Thus, the example terms “below” and “under” can encompass both an orientation of above and below (e.g., as described herein, a driving semiconductor layer 137 may be above or below a substrate buffer layer 126). The device may be otherwise oriented (e.g., rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein should be interpreted accordingly.

[0039] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the present disclosure. As used herein, the singular forms “a” and “an” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises,” “comprising,” “includes,” and “including,” when used in this specification, specify the presence of the stated features, integers, acts, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, acts, operations, elements, components, and/or groups thereof. As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items. Expressions such as “at least one of,” when preceding a list of elements, modify the entire list of elements and do not modify the individual elements of the list.

[0040] As used herein, the terms “substantially,” “about,” and similar terms are used as terms of approximation and not as terms of degree, and are intended to account for the inherent deviations in measured or calculated values that would be recognized by those of ordinary skill in the art. Further, the use of “may” when describing embodiments of the present disclosure refers to “one or more embodiments of the present disclosure.” As used herein, the terms “use,” “using,” and “used” may be considered synonymous with the terms “utilize,” “utilizing,” and “utilized,” respectively. Also, the term “exemplary” is intended to refer to an example or illustration.

[0041] FIG. 1 illustrates a cross-sectional view of an organic light emitting display according to an exemplary embodiment of the present disclosure. FIG. 2 illustrates an enlarged cross-sectional view of the organic light emitting display of FIG. 1.

[0042] A substrate 123 of FIG. 1 may, for example, be made of an inorganic material such as glass, an organic material such as polycarbonate, polymethyl methacrylate, polyethylene terephthalate, polyethylene naphthalate, polyamide, polyethersulfone, polyimide, or, a combination thereof, or a silicon wafer. As used herein, the terms “combination thereof” and “combinations thereof” may refer to a chemical combination (e.g., an alloy or chemical compound), a mixture, or a laminated structure of components.

[0043] A substrate buffer layer 126 may be provided on the substrate 123. The substrate buffer layer 126 prevents or reduces permeation of an impurity element and provides a flat surface.

[0044] In this case, the substrate buffer layer 126 may be made of various suitable materials that can provide the above-stated functions. For example, one of a silicon nitride (SiNx) layer, a silicon oxide (SiOx) layer, and a silicon oxynitride (SiOxNy) layer may be used as the substrate buffer layer 126. However, the substrate buffer layer 126 is not a required element or configuration, and may be omitted depending on a kind of substrate 123 and a process condition.

[0045] A driving semiconductor layer 137 may be formed above the substrate buffer layer 126. The driving semiconductor layer 137 may be made of a material including polysilicon. In some embodiments, the driving semiconductor layer 137 includes a channel region 135 in which impurities are not doped, and a source region 134 and a drain region 136 in which the impurities are doped at both sides of the channel region 135. In this case, the doped ion materials may be P-type impurities such as boron (B), and/or B₂H₆, which are mainly used. Here, the impurities may vary or be selected according to a kind of thin film transistor.

[0046] A gate insulating layer 127 made of a silicon nitride SiNx or a silicon oxide SiOx is formed on the driving semiconductor layer 137. A gate wire including a driving gate electrode 133 is formed on the gate insulating layer 127. In addition, the driving gate electrode 133 is formed to overlap at least a part of the driving semiconductor layer 137, for example, the channel region 135.

[0047] An interlayer insulating layer 128 covering the driving gate electrode 133 is formed on the gate insulating layer 127. A first contact hole 122a and a second contact hole 122b that expose the source area 134 and the drain area 136 of the driving semiconductor 137 are formed in the gate insulating layer 127 and the interlayer insulating layer 128. Like the gate insulating layer 127, the interlayer insulating layer 128 may be made of a material such as a silicon nitride SiNx or a silicon oxide SiOx.

[0048] In some embodiments, a data wire including a driving source electrode 131 and a driving drain electrode 132 may be provided on the interlayer insulating layer 128. Further, in some embodiments, the driving source electrode 131 and the driving drain electrode 132 are respectively coupled or connected with the source area 134 and the drain area 136 of the driving semiconductor layer 137 through the first contact hole 122a and the second contact hole 122b respectively formed in the interlayer insulating layer 128 and the gate insulating layer 127.

[0049] As described herein, the driving thin film transistor 130 may include the driving semiconductor layer 137, the driving gate electrode 133, the driving source electrode 131, and the driving drain electrode 132. The configuration of the driving thin film transistor 130 is not limited to the aforementioned example, and may be variously modified to any suitable configuration available in the art or which may be easily implemented by those skilled in the art.

[0050] In some embodiments, a planarization layer 124 covering the data wire is formed on the interlayer insulating layer 128. The planarization layer 124 serves to remove and planarize a step in order to increase emission efficiency of the organic light emitting element to be formed thereon.

Further, the planarization layer **124** has a third contact hole **122c** exposing a part of the drain electrode **132**.

[0051] The planarization layer **124** may be made of one or more materials selected from a polyacrylate resin, an epoxy resin, a phenolic resin, a polyamide resin, a polyimide resin, an unsaturated polyester resin, a polyphenylene ether resin, a polyphenylene sulfide resin, and benzocyclobutene (BCB).

[0052] Here, an exemplary embodiment according to the present disclosure is not limited to the aforementioned structure, and in some cases, one or more selected from the planarization layer **124** and the interlayer insulating layer **128** may be omitted.

[0053] In some embodiments, a first electrode of the organic light emitting element, e.g., a pixel electrode **160**, is formed on the planarization layer **124**. For example, the organic light emitting diode device includes a plurality of pixel electrodes **160** which are respectively disposed for each of a plurality of pixels. In some embodiments, the plurality of pixel electrodes **160** are spaced apart from each other. The pixel electrode **160** is coupled or connected to the drain electrode **132** through a third contact hole **122c** of the planarization layer **124**.

[0054] Further, a pixel defining layer **125** having an opening exposing the pixel electrode **160** is formed on the planarization layer **124**. For example, the pixel defining layer **125** has a plurality of openings, each of the openings corresponding to a respective one of the pixels. In this case, the light-emitting element layer **170** may be formed for each opening formed by the pixel defining layer **125**. Accordingly, a pixel area in which each light-emitting element layer **170** is formed by the pixel defining layer **125** may be defined.

[0055] In this case, the pixel electrode **160** is disposed to correspond to the opening of the pixel defining layer **125**. However, the pixel electrode **160** is not necessarily disposed only in the opening of the pixel defining layer **125**, but may be disposed below the pixel defining layer **125** such that a part of the pixel electrode **160** overlaps the pixel defining layer **125**.

[0056] The pixel defining layer **125** may be made of a resin, such as a polyacrylate resin and/or a polyimide, a silica-based inorganic material, and/or the like.

[0057] In some embodiments, a light-emitting element layer **170** is formed on the pixel electrode **160**. Hereinafter a structure of the light-emitting element layer **170** will be described in more detail.

[0058] A second electrode, e.g., a common electrode **180**, may be formed on the light-emitting element layer **170**. As described herein, an organic light emitting element LD may include the pixel electrode **160**, the light-emitting element layer **170**, and the common electrode **180**.

[0059] In some embodiments, the pixel electrode **160** and the common electrode **180** may be made of a transparent conductive material or a transfective or reflective conductive material. According to the kind of materials forming the pixel electrode **160** and/or the common electrode **180**, the organic light emitting diode device may be a top emission type (or kind), a bottom emission type (or kind), or a double-sided emission type (or kind).

[0060] In some embodiments, an overcoat **190** covering and protecting the common electrode **180** may be formed as an organic layer on the common electrode **180**.

[0061] In addition, a thin film encapsulation layer **121** may be formed on the overcoat **190**. The thin film encapsulation

layer **121** encapsulates and protects the organic light emitting element LD and a driving circuit part formed on the substrate **123** from the external environment.

[0062] In some embodiments, the thin film encapsulation layer **121** includes organic encapsulation layers **121a** and **121c**, and inorganic encapsulation layers **121b** and **121d**, which are alternately laminated. In FIG. 1, for example, a case where two organic encapsulation layers **121a** and **121c** and two inorganic encapsulation layers **121b** and **121d** are alternately laminated to configure the thin film encapsulation layer **121** is illustrated, but the present disclosure is not limited thereto.

[0063] Hereinafter, an organic light emitting element according to an exemplary embodiment of the present disclosure will be described with reference to FIG. 2.

[0064] Referring to FIG. 2, the organic light emitting element (part X in FIG. 1) according to an exemplary embodiment of the present disclosure includes a structure in which the first electrode **160**, a middle layer **165**, a hole transport layer **174**, an emission layer **175**, an electron transport layer **177**, an electron injection layer **179**, and the second electrode **180** are sequentially layered.

[0065] When the first electrode **160** is an anode, a material selected from materials having a high work function may be selected to form the first electrode **160** for easy hole injection. The first electrode **160** may be a transparent electrode or an opaque electrode (e.g., a reflective electrode). When the first electrode **160** is a transparent electrode, it may be made of indium-tin oxide (ITO), indium-zinc oxide (IZO), tin oxide (SnO₂), zinc oxide (ZnO), or a conductive oxide or combinations thereof, or a metal such as aluminum, silver, and/or magnesium, with a small thickness. When the first electrode **160** is an opaque electrode, it may be made of a metal such as aluminum, silver, and/or magnesium.

[0066] The first electrode **160** may be formed to be a two or more-layer structure including different kinds of materials. For example, the first electrode **160** may be formed to have a structure in which indium-tin oxide (ITO)/silver (Ag)/indium-tin oxide (ITO) are sequentially stacked.

[0067] The first electrode **160** may be formed by sputtering or vacuum deposition.

[0068] The middle layer **165** is provided on the first electrode **160**. The middle layer **165** is formed on the first electrode **160** to reduce an electron injection barrier by increasing a work function of the first electrode **160** and to smooth or smoothen the hole injection into the hole transport layer **174**.

[0069] For example, the middle layer **165** serves to reduce a work function difference between the first electrode **160** and the hole transport layer **174** for smooth hole injection to the emission layer **175** from the first electrode **160**.

[0070] In an exemplary embodiment of the present disclosure, the middle layer **165** may be a dipolar material formed of a first material including at least one selected from group 1 elements, group 2 elements, lanthanum-based metals, and transition metals, and a second material including at least one selected from halogen elements.

[0071] For example, the middle layer **165** according to the present exemplary embodiment may include at least one selected from iodinated group 1 elements, iodinated group 2 elements, iodinated lanthanum-based metals, and iodinated transition metals. For example, the middle layer **165** may be (include) at least one compound selected from LiI (lithium iodide), NaI (sodium iodide), KI (potassium iodide), RbI

(rubidium iodide), CsI (caesium iodide), CuI (copper iodide), AgI (silver iodide), TlI (thallium iodide), and CoI₂ (cobalt (II) iodide), but it is not limited thereto.

[0072] In the case that a halogenated group 1 element, a halogenated group 2 element, a halogenated lanthanum-based metal, or a halogenated transition metal compound is formed on the first electrode 160, a work function of the first electrode 160 is, for example, about 5.0 eV to about 7.0 eV. Compared to a case in which a work function of an ITO electrode where no middle layer 165 is formed is about 4.5 eV to about 4.8 eV, the first electrode 160 according to an exemplary embodiment of the present disclosure has an increased work function. Thus, a work function difference with the hole transport layer 174 provided on the first electrode 160 is reduced. For example, in some embodiments, a work function difference between the first electrode 160 and the hole transport layer 174 is, for example, less than or equal to about 0.5 eV.

[0073] In the present exemplary embodiment, the middle layer 165 may be formed using various suitable methods, such as a thermal evaporation method, a sputtering method, a chemical vapor deposition (CVD) method, an atomic layer deposition (ALD), a chemical solution deposition (CSD) method, and/or the like.

[0074] For example, the middle layer 165 according to the present exemplary embodiment is deposited by the thermal evaporation method. The thermal evaporation method is a vacuum deposition method, and when the thermal evaporation method is used, purity of a deposition material is excellent and thus efficiency uniformity can be excellent, and surface roughness is excellent as compared to a layer formed by a gas-based plasma deposition method. In some embodiments, when the thermal deposition method is used, a deposition thickness is very small and thus a variation range of the work function can be very precisely adjusted. Further, in the present exemplary embodiment, a metal (e.g., Sn, In, and/or the like) other than the halogen included in the middle layer 165 can be prevented from being spread into a hole transport layer (or such spread can be reduced), which is an organic material.

[0075] In some embodiments, the thickness of the middle layer 165 is between about 10 nm to about 20 nm. When the thickness of the middle layer 165 is less than 10 nm, the work function of the first electrode 160 cannot be adjusted (e.g., cannot be suitably adjusted) and when the thickness of the middle layer 165 exceeds 20 nm, a problem may occur in hole injection into the hole transport layer 174 from the first electrode 160 due to the middle layer 165.

[0076] The hole transport layer 174 is disposed on the middle layer 165. The hole transport layer 174 may serve to smoothly transport holes transmitted from a hole injection layer 172. The hole transport layer 174 may include an organic material. For example, the hole transport layer 174 may include NPD (N,N-dinaphthyl-N,N'-diphenyl benzi-dine), TPD (N,N'-bis-(3-methylphenyl)-N,N-bis-(phenyl)-benzidine), s-TAD, MTDATA (4,4',4''-tris(N-3-methylphenyl-N-phenyl-amino)-triphenylamine), and/or the like, but is not limited thereto.

[0077] In some embodiments, the thickness of the hole transport layer 174 may be about 15 nm to about 25 nm. For example, the thickness of the hole transport layer 174 may be about 20 nm. In the present exemplary embodiment, a hole injection material is included in the hole transport layer 174 as a modification of the hole transport layer 174, and thus the hole transport/injection layers may be formed as a single layer.

[0078] The emission layer 175 is disposed on the hole transport layer 174. The emission layer 175 includes an emission material that represents (e.g., emits) a set or specific color (e.g., a set color of light). For example, the emission layer 175 may display (e.g., emit) a basic color such as blue, green, or red, or a combination thereof (e.g., blue light, green light, red light, or a combination thereof).

[0079] The thickness of the emission layer 175 may be about 10 nm to about 50 nm. The emission layer 175 includes a host and a dopant. The emission layer 175 may include a material that emits red light, green light, blue light, and/or white light, and may be formed using a phosphorescent and/or fluorescent material.

[0080] When the emission layer 175 emits red light, the emission layer 175 may include a host material that includes CBP (carbazole biphenyl) or mCP (1,3-bis(carbazol-9-yl)), and may be formed of a phosphorescent material including at least one selected from the group consisting of PIQIr (acac) (bis(1-phenylisoquinoline)acetylacetonate iridium), PQIr(acac) (bis(1-phenylquinoline)acetylacetonate iridium), PQIr(tris(1-phenylquinoline)iridium), and PtOEP (octaethylporphyrin platinum), or a fluorescent material including PBD:Eu(DBM)3(Phen) or perylene, but the present disclosure is not limited thereto.

[0081] When the emission layer 175 emits green light, the emission layer 175 includes a host material including CBP or mCP, and may be made of a phosphorescent material including a dopant material including Ir(ppy)3(fac-tris(2-phenylpyridine)iridium) or a fluorescent material including Alq3(tris(8-hydroxyquinolino)aluminum), but the present disclosure is not limited thereto.

[0082] When the emission layer 175 emits blue light, the emission layer 175 includes a host material including CBP or mCP, and may be made of a phosphorescent material including a dopant that includes (4,6-F2ppy)2Irpic. Alternatively or additionally, the emission layer 175 may be made of a fluorescent material including at least one selected from the group consisting of spiro-DPVBi, spiro-6P, distyrylbenzene (DSB), distyrylarylene (DSA), a PFO-based polymer, and a PPV-based polymer, but the present disclosure is not limited thereto.

[0083] The electron transport layer 177 is disposed on the emission layer 175. The electron transport layer 177 may transfer electrons from the second electrode 180 to the emission layer 175. In addition, the electron transport layer 177 can prevent holes injected from the first electrode 160 from moving to the second electrode 180 through the emission layer 175 (or the electron transport layer 177 can reduce such movement). For example, the electron transport layer 177 helps holes and electrons bond (e.g., recombine) in the emission layer 175 by functioning as a hole blocking layer.

[0084] In some embodiments, the electron transport layer 177 may include an organic material. For example, the electron transport layer 177 may be made of any one or more selected from the group consisting of Alq3 (tris(8-hydroxyquinolino)-aluminum), PBD, TAZ, spiro-PBD, BALq, and SAiq, but the present disclosure is not limited thereto.

[0085] The electron injection layer 179 is disposed on the electron transport layer 177. The electron injection layer 179 serves to enhance electron injection to the electron transport layer 177 from the second electrode 180.

[0086] The thickness of the electron injection layer 179 may be about 1 nm to about 50 nm.

[0087] The electron injection layer 179 according to an exemplary embodiment of the present disclosure includes a metal-based halogen bipolar material. In some embodi-

ments, the electron injection layer **179** may be a bipolar material formed by combining a group 1 element, a group 2 element, a lanthanide metal such as Li, Na, K, Rb, Cs, Fr, Be, Mg, Ca, Sr, Ba, Ra, La, Yb, Lu, Tm, Ce, Pr, and Nd with a material selected from halogen materials such as F, Cl, Br, and I.

[0088] The electron injection layer **179** may be formed of a single layer of a metal-based halogen bipolar material, or may have a double-layered structure including metal and a metal-based halogen material (e.g., a double-layered structure including a metal layer and a metal-based halogen material layer).

[0089] The electron injection layer **179** may be formed using a sputtering method.

[0090] The second electrode **180** is provided on the electron injection layer **179**. When the second electrode **180** is a cathode, the second electrode **180** may include a material having a small work function for easy electron injection. For example, the material may be a metal, such as magnesium, calcium, sodium, potassium, titanium, indium, yttrium, lithium, gadolinium, aluminum, silver, tin, lead, cesium, barium, and/or the like, or an alloy thereof, or a multi-layered structure material, such as LiF/Al, LiO₂/Al, LiF/Ca, LiF/Al, and/or BaF₂/Ca, but the present disclosure is not limited thereto.

[0091] When the second electrode **180** is formed by alloys, an alloy ratio of the alloys is controlled based on a temperature of a deposition source, an atmosphere (e.g., the composition of the atmosphere), a degree of vacuum, and/or the like, and an appropriate or suitable alloy ratio may be selected.

[0092] The second electrode **180** may be formed of two or more layers.

[0093] In an exemplary embodiment of the present disclosure, the first electrode **60** indicates a work function increased due to the middle layer **165** formed on the first electrode **160**. This will be described in more detail with reference to Table 1. Table 1 shows the work function of the first electrode **160**, emission efficiency, and life-span of the light emitting display in the case that the middle layer **165** is formed on the first electrode **160** according to an exemplary embodiment of the present disclosure.

[0094] In this case, exemplary embodiment 1 and exemplary embodiment 2 are cases in which a middle layer **165** is formed of CuI, which is a transition metal-based halogen bipolar material, on a first electrode **160** formed of Ag/ITO.

[0095] Meanwhile, Comparative Example 1 is a case in which no middle layer **165** is formed (e.g., no middle layer **165** is formed on the first electrode **160**).

TABLE 1

	Work function	Driving voltage (V)	Emission efficiency (cd/A)	Life-span 97%
Comparative Example 1	4.8 eV	4.6	146.7	151 h
Exemplary embodiment 1	5.0 eV	4.4	151.0	170 h
Exemplary embodiment 2	5.1 eV	4.2	157.8	200 h

[0096] Emission efficiency implies (refers to) initial luminance, and life-span implies (refers to) the time taken for displaying luminance reduced to 97% from the initial emission luminance (100%).

[0097] Referring to Table 1, compared to the comparative example, exemplary embodiment 1 and exemplary embodi-

ment 2 respectively have work functions of greater than or equal to about 5.0 eV, and have higher emission efficiency. Further, the life-span of the organic light emitting element is also increased. This is because the first electrode **160**, on which the middle layer **165** is provided, has an increased work function such that the hole injection rate to the hole injection layer or the hole transport layer is increased, thereby increasing the combination with the electrons (e.g., the combination of the holes with the electrons). On the contrary, when the hole injection rate is decreased, the combination between the holes and the electrodes is decreased and the life-span of the organic light emitting element is reduced due to the remaining holes and electrons from the combination.

[0098] FIG. 3 illustrates a cross-sectional view of a partial exemplary variation of the organic light emitting element of FIG. 2.

[0099] Referring to FIG. 3, a hole injection layer **172** is added to the light-emitting layer **170** of the exemplary embodiment of FIG. 2. In the present exemplary embodiment, the hole injection layer **172** is provided between the hole transport layer **174** and the middle layer **165**. The hole injection layer **172** eases (e.g., improves) injection of holes to the hole transport layer **174** from the first electrode **160** on which the middle layer **165** is disposed. In the present exemplary embodiment, the hole injection layer **172** may be formed of an organic layer, but may include a bipolar material formed by combining a metal or non-metal having a work function of greater than or equal to 4.3 eV and halogen.

[0100] The metal or non-metal having a work function of greater than or equal to about 4.3 eV may be one selected from the group consisting of Ag, Au, B, Be, C, Co, Cr, Cu, Fe, Hg, Ir, Mo, Nb, Ni, Os, Pd, Pt, Re, Rh, Ru, Sb, Se, Si, Sn, Ta, Te, Ti, V, W, and Zn.

[0101] In the present exemplary embodiment, the middle layer **165** is disposed on the first electrode **160**. The middle layer **165** is formed on the first electrode **160** to reduce an electron injection barrier by increasing a work function of the first electrode **160** and to smoothen (e.g., improve) hole injection into the hole injection layer **172** and the hole transport layer **174**.

[0102] For example, the middle layer **165** serves to reduce a work function difference between the first electrode **160** and the hole injection layer **172** or the hole transport layer **174** for smooth hole injection to the emission layer **175** from the first electrode **160**.

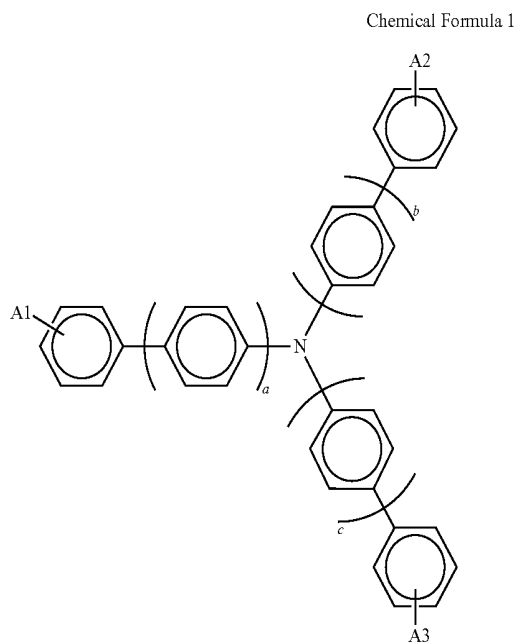
[0103] In addition to the above-described difference, the contents described with reference to FIG. 2 are applicable to the exemplary embodiment of FIG. 3.

[0104] FIG. 4 illustrates a cross-sectional view of a partial exemplary variation of the organic light emitting diode of FIG. 2.

[0105] Referring to FIG. 4, the emission layer **175** of the organic light emitting diode in FIG. 2 is deformed (e.g., modified) in the present exemplary variation. For example, an emission layer **175** of the present exemplary embodiment includes a red emission layer R, a green emission layer G, and a blue emission layer B, and an assistant layer BIL may be provided at a lower end of the blue emission layer B to increase emission efficiency of the blue emission layer B.

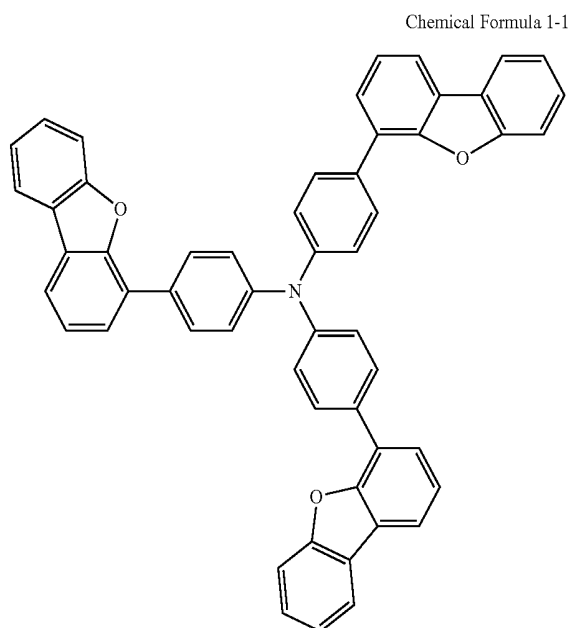
[0106] The red emission layer R may be about 30 nm to about 50 nm thick, the green emission layer G may be about 10 nm to about 30 nm thick, and the blue emission layer B may be about 10 nm to about 30 nm thick. The assistant layer BIL provided in a lower end of the blue emission layer B may be less than or equal to about 20 nm thick. The

assistant layer BIL serves to improve efficiency of the blue emission layer B by adjusting a hole charge balance. The assistant layer BIL may include a compound represented by Chemical Formula 1.



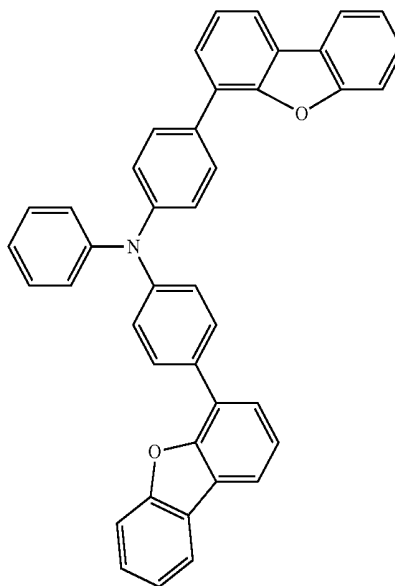
[0107] In Chemical Formula 1, A1, A2, and A3 may each be independently selected from an alkyl group, an aryl group, carbazole, dibenzothiophene, dibenzofuran (DBF), and biphenyl, and a, b, and c may each be independently selected from positive numbers of zero to four.

[0108] Examples of the compounds represented by Chemical Formula 1 include the following Chemical Formulas 1-1, 1-2, 1-3, 1-4, 1-5, and 1-6.

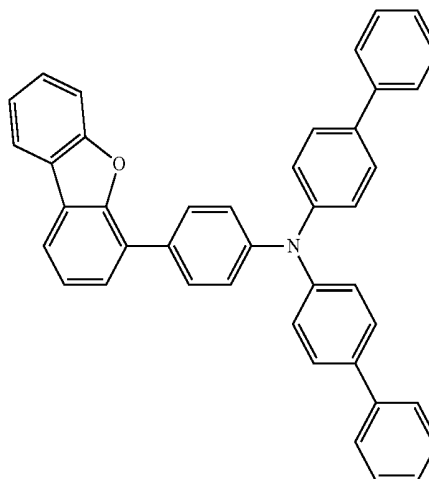


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Chemical Formula 1-2

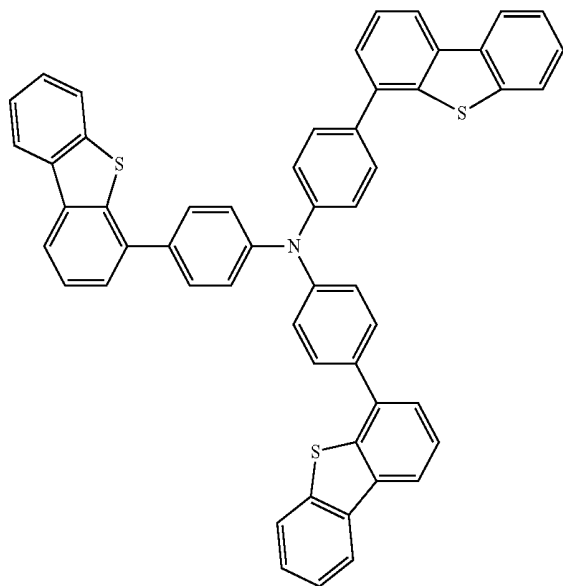


Chemical Formula 1-3



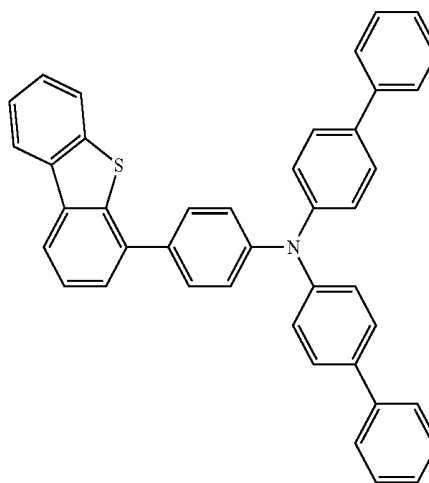
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Chemical Formula 1-4



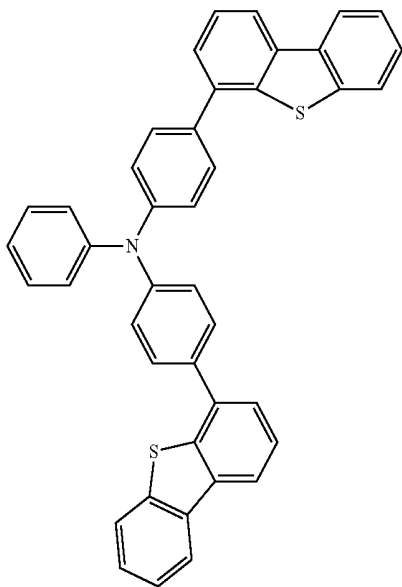
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Chemical Formula 1-6

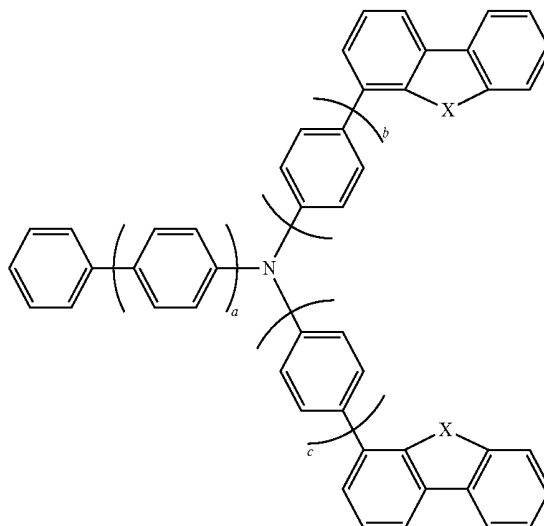


[0109] In another exemplary embodiment, the assistant layer BIL may include a compound represented by Chemical Formula 2.

Chemical Formula 1-5



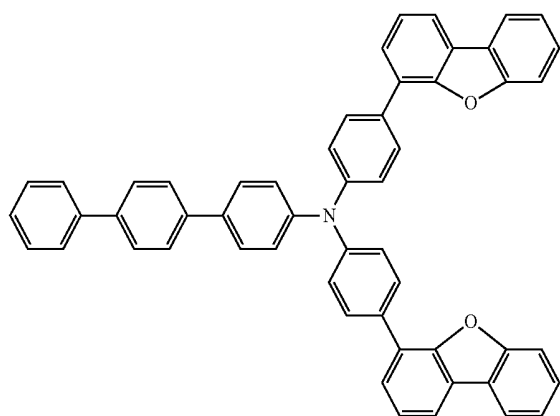
Chemical Formula 2



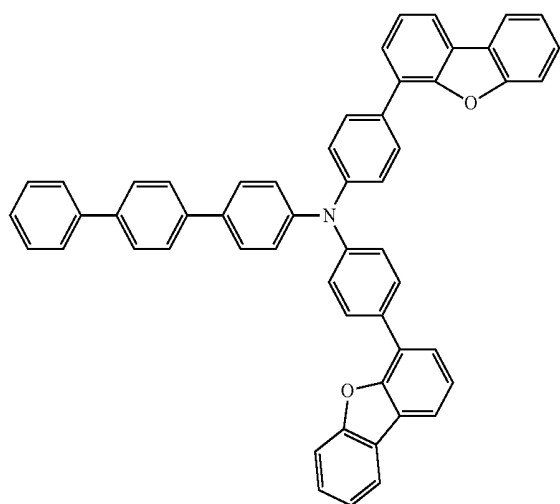
[0110] In Chemical Formula 2, a may be 0 to 3, b and c may each independently be 0 to 3, X may be selected from O, N, or S, and each X may be the same or different from each other.

[0111] Examples of the compound represented by Chemical Formula 2 include Chemical Formulas 2-1, 2-2, 2-3, 2-4, 2-5, and 2-6.

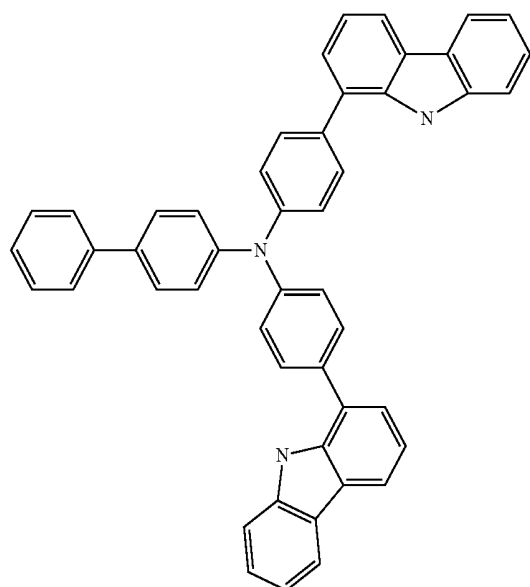
Chemical Formula 2-1



Chemical Formula 2-2

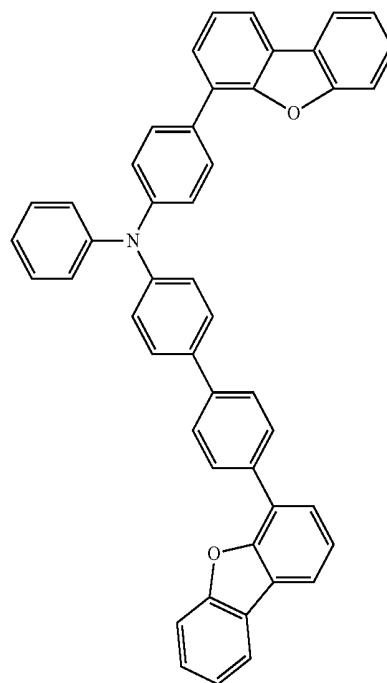


Chemical Formula 2-3

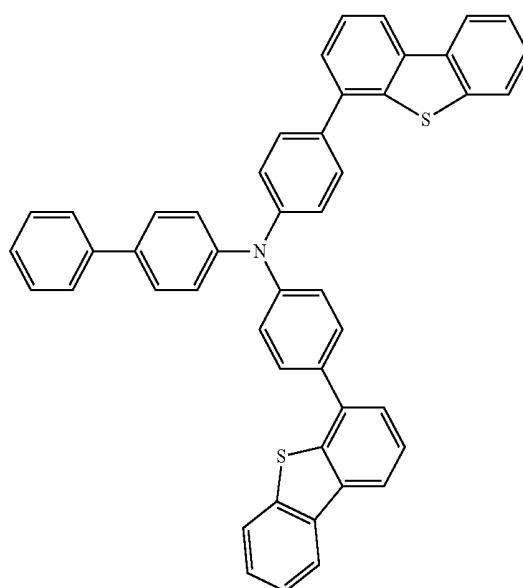


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Chemical Formula 2-4

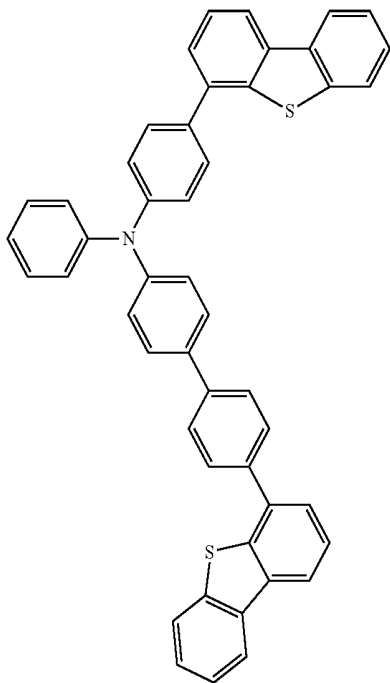


Chemical Formula 2-5

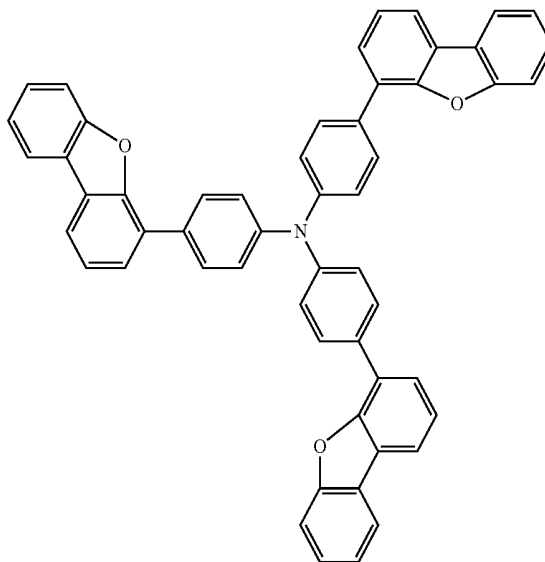


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Chemical Formula 2-6

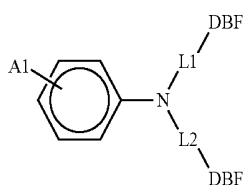


Chemical Formula 1-1



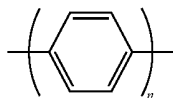
Composition Example

[0112] In another exemplary embodiment, the assistant layer BIL may include a compound represented by Chemical Formula 3.



Chemical Formula 3

[0113] In Chemical Formula 3, A1 may be an alkyl group, an aryl group, carbazole, dibenzothiophene, or dibenzofuran (DBF), L1 and L2 may be



(where n is 0 to 3), and each DBF coupled or connected to L1 or L2 may, optionally, be replaced by carbazole or dibenzothiophene.

[0114] Hereinafter, a composition method (e.g., synthesis) of the assistant layer BIL according to an exemplary embodiment of the present disclosure will be described in more detail. For example, the composition method (e.g., synthesis) of the following Chemical formula 1-1 is described in more detail.

[0115] Under an argon atmosphere, 6.3 g of 4-dibenzofuran boronic acid, 4.8 g of 4,4',4''-tribromotriphenylamine, 104 mg of tetrakis(triphenylphosphine)palladium (Pd(PPh₃)₄), 48 ml (2 M) of a sodium carbonate (Na₂CO₃) solution, and 48 ml of toluene were put in a 300 ml 3-neck flask, and reacted at 80° C. for eight hours. The reaction solution was extracted with toluene/water, and dried with anhydrous sodium sulfate. The resultant was condensed under low pressure, and 3.9 g of a yellowish-white powder was obtained through column purification of the obtained crude product.

[0116] In FIG. 4, a red resonance assistant layer R' may be provided below the red emission layer R, and a green resonance assistant layer G' may be provided below the green emission layer G. The red resonance assistant layer R' and the green resonance assistant layer G' are layers to be added in order to set a resonant distance for each color. In some embodiments, a separate resonance assistant layer provided between the hole transport layer 174 and the blue light emission layer B and the assistant layer BIL may not be formed below the blue emission layer B and the assistant layer BIL corresponding to the red emission layer R or the green emission layer G.

[0117] The above descriptions may be applied to the exemplary embodiment of FIG. 4, except for the above-described differences.

[0118] While the subject matter of this disclosure has been described in connection with what is presently considered to be practical exemplary embodiments, it is to be understood that the present disclosure is not limited to the disclosed embodiments, but, on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims, and equivalents thereof.

What is claimed is:

1. An organic light emitting diode comprising:
 - a first electrode and a second electrode that face each other;
 - a middle layer on the first electrode;
 - a hole transport layer on the middle layer; and
 - an emission layer between the hole transport layer and the second electrode,

wherein the middle layer comprises a bipolar material formed by combining a first material comprising at least one selected from a group 1 element, a group 2 element, and a lanthanide metal, with a second material comprising a halogen element.

2. The organic light emitting diode of claim 1, wherein the middle layer comprises at least one selected from an iodinated group 1 element, an iodinated group 2 element, an iodinated lanthanide metal, and an iodinated transition metal.

3. The organic light emitting diode of claim 2, wherein the middle layer comprises at least one compound selected from LiI, NaI, KI, RbI, CsI, CuI, AgI, TlI, and CoI₂.

4. The organic light emitting diode of claim 3, wherein the thickness of the middle layer is about 10 nm to about 20 nm.

5. The organic light emitting diode of claim 4, further comprising a hole injection layer provided between the middle layer and the hole transport layer,

wherein the hole injection layer and the hole transport layer comprise an organic material.

6. The organic light emitting diode of claim 1, wherein a work function of the first electrode is about 5.0 eV to about 7.0 eV.

7. The organic light emitting diode of claim 6, wherein a work function difference between the first electrode and the hole transport layer is less than or equal to about 0.5 eV.

8. An organic light emitting diode display comprising:

a substrate;

a thin film transistor on the substrate; and

an organic light emitting diode coupled to the thin film transistor,

wherein the organic light emitting diode comprises:

a first electrode and a second electrode facing each other;

a middle layer on the first electrode;

a hole transport layer on the middle layer; and

an emission layer on the hole transport layer,

wherein the middle layer comprises a bipolar material formed by combining a first material comprising at least one selected from a group 1 element, a group 2 element, and a lanthanide metal, with a second material comprising a halogen element.

9. The organic light emitting diode display of claim 8, wherein the middle layer comprises at least one selected from an iodinated group 1 element, an iodinated group 2 element, an iodinated lanthanide metal, and an iodinated transition metal.

10. The organic light emitting diode display of claim 8, wherein a work function of the first electrode is about 5.0 eV to about 7.0 eV.

11. The organic light emitting diode display of claim 10, wherein a work function difference between the first electrode and the hole transport layer is less than or equal to about 0.5 eV.

12. The organic light emitting diode display of claim 8, further comprising a hole injection layer between the middle layer and the hole transport layer,

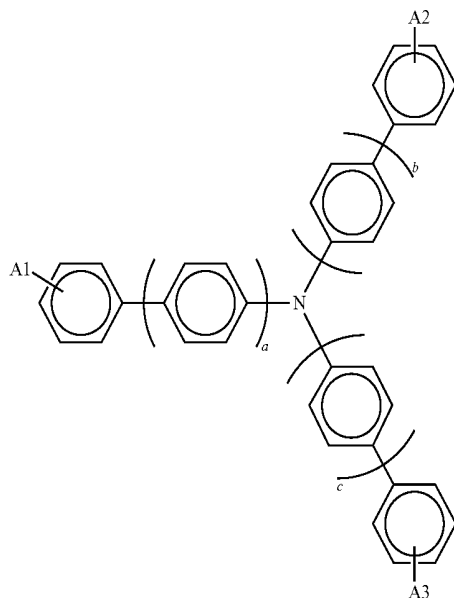
wherein the hole injection layer and the hole transport layer each comprise an organic material.

13. The organic light emitting diode display of claim 8, wherein the emission layer comprises a red emission layer, a green emission layer, and a blue emission layer, and further comprises an assistant layer at a lower end of the blue emission layer.

14. The organic light emitting diode display of claim 13, further comprising a red resonance assistant layer at a lower end of the red emission layer and a green resonance assistant layer at a lower end of the green emission layer.

15. The organic light emitting diode display of claim 13, wherein the assistant layer comprises a compound represented by Chemical Formula 1:

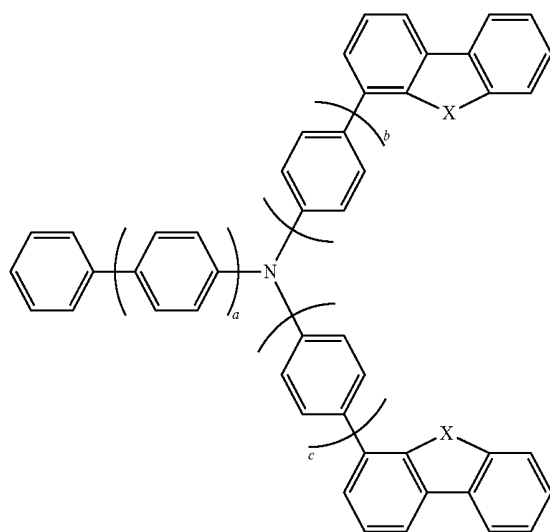
Chemical Formula 1



wherein, in Chemical Formula 1, A1, A2, and A3 are each independently selected from an alkyl group, an aryl group, carbazole, dibenzothiophene, dibenzofuran (DBF), and biphenyl, and a, b, and c are each independently selected from positive numbers of zero to four.

16. The organic light emitting diode display of claim 13, wherein the assistant layer comprises a compound represented by Chemical Formula 2:

Chemical Formula 2



wherein, in Chemical Formula 2, a is selected from 0 to 3, and b and c are each independently selected from 0 to 3, X is selected from O, N, or S, and each X is the same as or different from each other.

* * * * *

专利名称(译)	有机发光二极管和包括其的有机发光二极管显示器		
公开(公告)号	US20160351819A1	公开(公告)日	2016-12-01
申请号	US15/004638	申请日	2016-01-22
[标]申请(专利权)人(译)	三星显示有限公司		
申请(专利权)人(译)	三星DISPLAY CO. , LTD.		
当前申请(专利权)人(译)	三星DISPLAY CO. , LTD.		
[标]发明人	KIM DONG CHAN KIM WON JONG KIM EUNG DO SEO DONG KYU LEE JI HYE IM DA HEA YIM SANG HOON HAN WON SUK		
发明人	KIM, DONG CHAN KIM, WON JONG KIM, EUNG DO SEO, DONG KYU LEE, JI HYE IM, DA HEA YIM, SANG HOON HAN, WON SUK		
IPC分类号	H01L51/00 H01L27/32		
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优先权	1020150077495 2015-06-01 KR		
外部链接	Espacenet USPTO		

摘要(译)

有机发光二极管包括：彼此面对的第一电极和第二电极；在所述第一电极上的中间层；在所述中间层上的空穴传输层；以及在所述空穴传输层和所述第二电极之间的发射层，其中所述中间层包括通过将包括至少选自第1族元素，第2族元素，镧系金属的第一材料与第二材料结合而形成的双极材料，包括卤素元素的材料。

