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Organic light emitting diode and organic light emitting device including the same

Abstract

An organic light emitting diode and an organic light emitting device including the same are discussed. The organic light emitting diode can include a first electrode, a second electrode facing the first electrode, and a first emitting part including a green emitting material layer and positioned between the first and second electrodes. The green emitting material layer can include a first host, a second host and a dopant, wherein at least one of the first host and the second host is deuterated.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS

(1) The present application claims the priority benefit of Korean Patent Application No. 10-2020-0186055 filed in the Republic of Korea on Dec. 29, 2020, the entire contents of which are hereby

incorporated by reference into the present application.

BACKGROUND

Field of Technology

(2) The present disclosure relates to an organic light emitting diode (OLED) and an organic light emitting device, and more specifically, to an organic light emitting diode (OLED) having an improved lifespan and an organic light emitting device including the same.

Background Discussion

(3) As requests for a flat panel display device having a small occupied area have been increased, an organic light emitting display device including an OLED has been the subject of recent research and development.

(4) The OLED emits light by injecting electrons from a cathode as an electron injection electrode and holes from an anode as a hole injection electrode into an emitting material layer (EML), combining the electrons with the holes, generating an exciton, and transforming the exciton from an excited state to a ground state. A flexible substrate, for example, a plastic substrate, can be used as a base substrate where elements are formed. In addition, the organic light emitting display device can be operated at a voltage (e.g., 10V or below) lower than a voltage required to operate other display devices. Moreover, the organic light emitting display device has advantages in the power consumption and the color sense.

(5) The OLED includes a first electrode as an anode over a substrate, a second electrode, which is spaced apart from and faces the first electrode, and an organic emitting layer therebetween.

(6) The materials in the organic emitting layer have been studied and researched, but there can be still a limitation in the lifespan of the OLED.

SUMMARY OF THE DISCLOSURE

(7) The present disclosure is directed to an OLED and an organic light emitting device including the OLED that substantially obviate one or more of the problems associated with the limitations and disadvantages of the related conventional art.

(8) Additional features and advantages of the present disclosure are set forth in the description which follows, and will be apparent from the description, or evident by practice of the present disclosure. The objectives and other advantages of the present disclosure are realized and attained by the features described herein as well as in the appended drawings.

(9) To achieve these and other advantages in accordance with the purpose of the embodiments of the present disclosure, as described herein, an aspect of the present disclosure is an organic light emitting diode comprising a first electrode; a second electrode facing the first electrode; and a first emitting part including a green emitting material layer and positioned between the first and second electrodes, the green emitting material layer including a first host, a second host and a dopant, wherein the first host is represented by Formula 1-1:

(10) ##STR00001##

wherein X is oxygen or sulfur, a1 is an integer of 0 to 10, wherein b1 is an integer of 0 to 4, and each of c1 and d1 is independently an integer of 0 to 5, wherein the second host is represented by Formula 2-1:

(11) ##STR00002##

wherein a2 is an integer of 0 to 14, and each of b2 and c2 is independently an integer of 0 to 9, and wherein at least one of a1, a2, b1, b2, c1, c2 and d1 is a positive integer.

(12) Another aspect of the present disclosure is an organic light emitting device comprising a substrate; and the above organic light emitting diode positioned on the substrate.

(13) It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to further explain the present disclosure as claimed.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

- (1) The accompanying drawings, which are included to provide a further understanding of the present disclosure and are incorporated in and constitute a part of this specification, illustrate embodiments of the present disclosure and together with the description serve to explain the principles of the present disclosure.
- (2) FIG. 1 is a schematic circuit diagram illustrating an organic light emitting display device of the present disclosure.
- (3) FIG. 2 is a schematic cross-sectional view illustrating an organic light emitting display device according to a first embodiment of the present disclosure.
- (4) FIG. 3 is a schematic cross-sectional view illustrating an OLED according to a second embodiment.
- (5) FIG. 4 is a schematic cross-sectional view illustrating an organic light emitting display device according to a third embodiment of the present disclosure.
- (6) FIG. 5 is a schematic cross-sectional view illustrating an OLED according to a fourth embodiment of the present disclosure.
- (7) FIG. 6 is a schematic cross-sectional view illustrating an OLED according to a fifth embodiment.

DETAILED DESCRIPTION OF THE EMBODIMENTS

- (8) Reference will now be made in detail to some of the examples and preferred embodiments, which are illustrated in the accompanying drawings.
- (9) In the present disclosure, an aryl group, an arylene group, a heteroaryl group and a heteroarylene group can be unsubstituted or substituted with alkyl and/or aryl without specific definition.
- (10) FIG. 1 is a schematic circuit diagram illustrating an organic light emitting display device of the present disclosure. All the components of each organic light emitting display device according to all embodiments of the present disclosure are operatively coupled and configured.
- (11) As illustrated in FIG. 1, a gate line GL and a data line DL, which cross each other to define a pixel region (pixel) P, and a power line PL are formed in an organic light emitting display device. A switching thin film transistor (TFT) Ts, a driving TFT Td, a storage capacitor Cst and an OLED D are formed in the pixel region P. The pixel region P can include a red pixel region, a green pixel region and a blue pixel region. In addition, the pixel region P can further include a white pixel region.
- (12) The switching thin film transistor Ts is connected to the gate line GL and the data line DL, and the driving thin film transistor Td and the storage capacitor Cst are connected between the switching thin film transistor Ts and the power line PL. The OLED D is connected to the driving thin film transistor Td. When the switching thin film transistor Ts is turned on by the gate signal applied through the gate line GL, the data signal applied through the data line DL is applied to a gate electrode of the driving thin film transistor Td and one electrode of the storage capacitor Cst through the switching thin film transistor Ts.
- (13) The driving thin film transistor Td is turned on by the data signal applied into the gate electrode so that a current proportional to the data signal is supplied from the power line PL to the OLED D through the driving thin film transistor Td. The OLED D emits light having a luminance proportional to the current flowing through the driving thin film transistor Td. In this case, the storage capacitor Cst is charged with a voltage proportional to the data signal so that the voltage of the gate electrode in the driving thin film transistor Td is kept constant during one frame. Therefore, the organic light emitting display device can display a desired image.
- (14) FIG. 2 is a schematic cross-sectional view illustrating an organic light emitting display device

according to a first embodiment of the present disclosure.

(15) As illustrated in FIG. 2, the organic light emitting display device **100** includes a substrate **110**, a TFT Tr and an OLED D connected to the TFT Tr. For example, the organic light emitting display device **100** can include a red pixel region, a green pixel region and a blue pixel region, and the OLED D can be formed in each of the red, green and blue pixel regions. Namely, the OLEDs D emitting red light, green light and blue light can be provided in the red, green and blue pixel regions, respectively.

(16) The substrate **110** can be a glass substrate or a flexible substrate. For example, the flexible substrate can be a polyimide (PI) substrate, a polyethersulfone (PES) substrate, a polyethylenenaphthalate (PEN) substrate, a polyethylene terephthalate (PET) substrate or a polycarbonate (PC) substrate.

(17) A buffer layer **120** is formed on the substrate, and the TFT Tr is formed on the buffer layer **120**. The buffer layer **120** can be omitted.

(18) A semiconductor layer **122** is formed on the buffer layer **120**. The semiconductor layer **122** can include an oxide semiconductor material or polycrystalline silicon.

(19) When the semiconductor layer **122** includes the oxide semiconductor material, a light-shielding pattern can be formed under the semiconductor layer **122**. The light to the semiconductor layer **122** is shielded or blocked by the light-shielding pattern such that thermal degradation of the semiconductor layer **122** can be prevented. On the other hand, when the semiconductor layer **122** includes polycrystalline silicon, impurities can be doped into both sides of the semiconductor layer **122**.

(20) A gate insulating layer **124** is formed on the semiconductor layer **122**. The gate insulating layer **124** can be formed of an inorganic insulating material such as silicon oxide or silicon nitride.

(21) A gate electrode **130**, which is formed of a conductive material, e.g., metal, is formed on the gate insulating layer **124** to correspond to a center of the semiconductor layer **122**.

(22) In FIG. 2, the gate insulating layer **124** is formed on an entire surface of the substrate **110**. Alternatively, the gate insulating layer **124** can be patterned to have the same shape as the gate electrode **130**.

(23) An interlayer insulating layer **132**, which is formed of an insulating material, is formed on the gate electrode **130**. The interlayer insulating layer **132** can be formed of an inorganic insulating material, e.g., silicon oxide or silicon nitride, or an organic insulating material, e.g., benzocyclobutene or photo-acryl.

(24) The interlayer insulating layer **132** includes first and second contact holes **134** and **136** exposing both sides of the semiconductor layer **122**. The first and second contact holes **134** and **136** are positioned at both sides of the gate electrode **130** to be spaced apart from the gate electrode **130**.

(25) The first and second contact holes **134** and **136** are formed through the gate insulating layer **124**. Alternatively, when the gate insulating layer **124** is patterned to have the same shape as the gate electrode **130**, the first and second contact holes **134** and **136** is formed only through the interlayer insulating layer **132**.

(26) A source electrode **140** and a drain electrode **142**, which are formed of a conductive material, e.g., metal, are formed on the interlayer insulating layer **132**.

(27) The source electrode **140** and the drain electrode **142** are spaced apart from each other with respect to the gate electrode **130** and respectively contact both sides of the semiconductor layer **122** through the first and second contact holes **134** and **136**.

(28) The semiconductor layer **122**, the gate electrode **130**, the source electrode **140** and the drain electrode **142** constitute the TFT Tr. The TFT Tr serves as a driving element. Namely, the TFT Tr can correspond to the driving TFT Td (of FIG. 1).

(29) In the TFT Tr, the gate electrode **130**, the source electrode **140**, and the drain electrode **142** are positioned over the semiconductor layer **122**. Namely, the TFT Tr has a coplanar structure.

(30) Alternatively, in the TFT Tr, the gate electrode can be positioned under the semiconductor layer, and the source and drain electrodes can be positioned over the semiconductor layer such that the TFT Tr can have an inverted staggered structure. In this instance, the semiconductor layer can include amorphous silicon.

(31) The gate line and the data line cross each other to define the pixel region, and the switching TFT is formed to be connected to the gate and data lines. The switching TFT is connected to the TFT Tr as the driving element.

(32) In addition, the power line, which can be formed to be parallel to and spaced apart from one of the gate and data lines, and the storage capacitor for maintaining the voltage of the gate electrode of the TFT Tr in one frame can be further formed.

(33) A planarization layer **150**, which includes a drain contact hole **152** exposing the drain electrode **142** of the TFT Tr, is formed to cover the TFT Tr.

(34) A first electrode **160**, which is connected to the drain electrode **142** of the TFT Tr through the drain contact hole **152**, is separately formed in each pixel region and on the planarization layer **150**. The first electrode **160** can be an anode and can be formed of a conductive material having a relatively high work function. For example, the first electrode **160** can be formed of a transparent conductive material such as indium-tin-oxide (ITO) or indium-zinc-oxide (IZO).

(35) When the organic light emitting display device **100** is operated in a bottom-emission type, the first electrode **160** can have a single-layered structure of the transparent conductive material layer. When the organic light emitting display device **100** is operated in a top-emission type, a reflection electrode or a reflection layer can be formed under the first electrode **160**. For example, the reflection electrode or the reflection layer can be formed of silver (Ag) or aluminum-palladium-copper (APC) alloy. In this instance, the first electrode **160** can have a triple-layered structure of ITO/Ag/ITO or ITO/APC/ITO.

(36) A bank layer **166** is formed on the planarization layer **150** to cover an edge of the first electrode **160**. Namely, the bank layer **166** is positioned at a boundary of the pixel region and exposes a center of the first electrode **160** in the pixel region.

(37) An organic emitting layer **162** is formed on the first electrode **160**. The organic emitting layer **162** includes a single emitting part including an emitting material layer (EML). Alternatively, the organic emitting layer **162** includes a plurality of emitting parts, e.g., at least two emitting parts, each including the EML. In addition, the organic emitting layer **162** can further include a charge generation layer between adjacent emitting parts.

(38) Each emitting part can further include at least one of a hole injection layer (HIL), a hole transporting layer (HTL), an electron blocking layer (EBL), a hole blocking layer (HBL), an electron transporting layer (ETL) and an electron injection layer (EIL) such that each emitting part has a multi-layered structure.

(39) The organic emitting layer **162** is separated in each of the red, green and blue pixel regions. As illustrated below, in the OLED D in the green pixel region, the EML includes a first host including a fused-hetero ring moiety and a second host including a biscarbazole moiety, and at least one of the fused-hetero ring moiety and the biscarbazole moiety is deuterated. As a result, the lifespan of the OLED D and the organic light emitting display device **100** are improved.

(40) The second electrode **164** is formed over the substrate **110** where the organic emitting layer **162** is formed. The second electrode **164** covers an entire surface of the display area and can be formed of a conductive material having a relatively low work function to serve as a cathode. For example, the second electrode **164** can be formed of aluminum (Al), magnesium (Mg), silver (Ag) or their alloy, e.g., Al—Mg alloy (AlMg) or Ag—Mg alloy (MgAg). In the top-emission type organic light emitting display device **100**, the second electrode **164** can have a thin profile (small thickness) to provide a light transmittance property (or a semi-transmittance property).

(41) The first electrode **160**, the organic emitting layer **162** and the second electrode **164** constitute the OLED D.

(42) An encapsulation film **170** is formed on the second electrode **164** to prevent penetration of moisture into the OLED D. The encapsulation film **170** includes a first inorganic insulating layer **172**, an organic insulating layer **174** and a second inorganic insulating layer **176** sequentially stacked, but it is not limited thereto. The encapsulation film **170** can be omitted.

(43) The organic light emitting display device **100** can further include a polarization plate for reducing an ambient light reflection. For example, the polarization plate can be a circular polarization plate. In the bottom-emission type organic light emitting display device **100**, the polarization plate can be disposed under the substrate **110**. In the top-emission type organic light emitting display device **100**, the polarization plate can be disposed on or over the encapsulation film **170**.

(44) In addition, in the top-emission type organic light emitting display device **100**, a cover window can be attached to the encapsulation film **170** or the polarization plate. In this instance, the substrate **110** and the cover window have a flexible property such that a flexible organic light emitting display device can be provided.

(45) FIG. 3 is a schematic cross-sectional view illustrating an OLED according to a second embodiment.

(46) As shown in FIG. 3, the OLED D includes the first and second electrodes **160** and **164** facing each other and the organic emitting layer **162** between the first and second electrodes **160** and **164**. The organic emitting layer **162** includes a green EML **230**.

(47) The organic light emitting display device **100** (of FIG. 2) can include a red pixel region, a green pixel region and a blue pixel region, and the OLED D can be positioned in the green pixel region.

(48) The first electrode **160** is an anode injecting a hole, and the second electrode **164** is a cathode injecting an electron. One of the first and second electrodes **160** and **164** is a reflection electrode, and the other one of the first and second electrodes **160** and **164** is a transparent electrode (or a semi-transparent electrode).

(49) For example, the first electrode **160** can include a transparent conductive material, e.g., ITO or IZO, and the second electrode **164** can be formed of Al, Mg, Ag, AlMg or MgAg.

(50) The organic emitting layer **162** can further include at least one of an HTL **220** under the green EML **230** and an ETL **240** over the green EML **230**. Namely, the HTL **220** is disposed between the green EML **230** and the first electrode **160**, and the ETL **240** is disposed between the green EML **230** and the second electrode **164**.

(51) In addition, the organic emitting layer **162** can further include an HIL **210** under the HTL **220** and an EIL **250** over the ETL **240**.

(52) The organic emitting layer **162** can further include at least one of an EBL between the HTL **220** and the green EML **230** and an HBL between the green EML **230** and the ETL **240**.

(53) In the OLED D, the green EML **230** constitutes an emitting part, or the green EML **230** with at least one of the HIL **210**, the HTL **220**, the EBL, the HBL, the ETL **240** and the EIL **250** constitute the emitting part.

(54) The green EML **230** includes a first host **232** as a first compound and a second host **234** as a second compound. The green EML **230** can have a thickness of 50 to 600 Å, preferably 200 to 400 Å. In the green EML **230**, a weight % ratio of the first host **232** to the second host **234** can be 1:9 to 9:1, preferably 2:8 to 8:2, and more preferably 3:7 to 7:3. In an embodiment, in the green EML **230**, the weight % of the first host **232** can be smaller than that of the second host **234**. For example, in the green EML **230**, the weight % ratio of the first host **232** to the second host **234** can be 2:8 to 4:6, preferably 3:7.

(55) The first compound being the first host **232** in the green EML **230** includes a fused-hetero ring moiety (e.g., a fused-heterocyclic moiety), a diphenyltriazine moiety and a phenylene linker linking the fused-hetero ring moiety and the diphenyltriazine moiety. In addition, the second compound being the second host **234** in the green EML **230** includes a biscarbazole moiety and a biphenyl

moiety linked (connected or combined) to both sides of the biscarbazole moiety. The first host **232** can be an N-type host, and the second host **234** can be a P-type host.

(56) At least one of the first and second hosts **232** and **234** is substituted with deuterium atom. In other words, at least one of the first and second hosts **232** and **234** is deuterated. When at least one of hydrogen atoms in the first host **232** is substituted with deuterium atom (e.g., partially deuterated or wholly deuterated), the second host **234** is not substituted with deuterium atom (e.g., non-deuterated), or at least one of hydrogen atoms in the second host **234** is substituted with deuterium atom (e.g., partially deuterated or wholly deuterated). Alternatively, when the second host **234** is partially or wholly deuterated, the first host **232** is non-deuterated, partially deuterated or wholly deuterated.

(57) The first host **232** (i.e., the first compound) is represented by Formula 1-1.

(58) ##STR00003##

(59) In Formula 1-1, X is oxygen (O) or sulfur (S). In Formula 1-1, a1 is an integer of 0 to 10, b1 is an integer of 0 to 4, and each of c1 and d1 is independently an integer of 0 to 5. (In Formula 1-1, D denotes deuterium atom, and each of a1, b1, c1 and d1 denotes a number of deuterium atom.)

(60) The second host **234** (i.e., the second compound) is represented by Formula 2-1.

(61) ##STR00004##

(62) In Formula 2-1, a2 is an integer of 0 to 14, b2 is an integer of 0 to 9, and c2 is an integer of 0 to 9. (In Formula 2-1, D denotes deuterium atom, and each of a2, b2, and c2 denotes a number of deuterium atom.)

(63) In this instance, at least one of a1, a2, b1, b2, c1, c2 and d1 is a positive integer.

(64) For example, at least one of the fused-hetero ring moiety, e.g., benzofurocarbazole or benzothienocarbazole, of the first host **232** and the biscarbazole moiety of the second host **234** can be deuterated. Namely, the fused-hetero ring moiety of the first host **232** is partially or wholly deuterated, or the biscarbazole moiety of the second host **234** is partially or wholly deuterated. Alternatively, the fused-hetero ring moiety of the first host **232** is partially or wholly deuterated, and the biscarbazole moiety of the second host **234** is partially or wholly deuterated.

(65) Namely, in the OLED D of the present disclosure, the green EML **230** includes the first host **232** being the compound in Formula 1-1 and the second host **234** being the compound in Formula 2-1, and at least one of a1 and a2 in Formulas 1-1 and 2-1 can be a positive integer.

(66) For example, when the first host **232** in Formula 1-1 is represented by Formula 1-2 (i.e., a1=1~10 (positive integer) and each of b1, c1 and d1 is 0), the second host **234** can be represented by Formula 2-1. (when a1=1~10 and each of b1, c1 and d1 is 0, a2=0~14 and each of b2 and c2 is 0~9)

(67) ##STR00005##

(68) Alternatively, in the second host **234**, the biscarbazole moiety except the biphenyl moiety can be partially or wholly deuterated. In this instance, the first host **232** can be non-deuterated, partially deuterated or wholly deuterated.

(69) For example, when the second host **234** in Formula 2-1 is represented by Formula 2-2 (i.e., a2=1-14 (positive integer) and each of b2 and c2 is 0), the first host **232** can be represented by Formula 1-1. (when a2=1~14 and each of b2 and c2 is 0, a1=0~10, b1=0~4 and each of c1 and d1 is 0~5)

(70) ##STR00006##

(71) The first compound in Formula 1-1 can be selected from the compounds in Formula 3, and the first compound in Formula 1-2 can be the compound Host1-4 or the compound Host2-4.

(72) ##STR00007## ##STR00008## ##STR00009## ##STR00010##

(73) The second compound in Formula 2-1 can be selected from the compounds in Formula 4, and the second compound in Formula 2-2 can be the compound Host3-3.

(74) ##STR00011## ##STR00012##

(75) A case of the first host **232** being the compound Host1-1 or the compound Host2-1 and the

second host **234** being the compound 3-1 is excluded from the present disclosure.

(76) In the OLED D of the present disclosure, the green EML **230** includes the first host **232** in Formula 1-1 and the second host **234** in Formula 2-1, and at least one of the first and second hosts **232** and **234** is deuterated. As a result, the lifespan of the OLED D and the organic light emitting display device **100** is improved.

(77) In addition, when only the fused-hetero ring moiety in the first host **232** is deuterated and/or only the biscarbazole moiety in the second host **234** is deuterated, the lifespan of the OLED D and the organic light emitting display device **100** is further improved.

(78) [Synthesis]

(79) 1. Synthesis of the Compound Host1-1

(80) ##STR00013##

(81) In a flask, the compound A1 (13.67 g, 50 mmol), the compound C1 (23.30 g, 60 mmol), Pd(OAc).sub.2 (0.55 g, 2.49 mmol), S-Phos (2.04 g, 4.98 mmol), NaOt-Bu (8.6 g, 90.14 mmol) and o-xylene (500 ml) were mixed and heated at 185° C. for 4 hours. After cooling to room temperature, distilled water was added. The organic layer was extracted with ethyl acetate and distilled under reduced pressure. The obtained solid was separated by a column to obtain the compound Host1-1 (20.3 g, yield: 70.0%).

(82) 2. Synthesis of the Compound Host2-1

(83) ##STR00014##

(84) In a flask, the compound B1 (12.87 g, 50 mmol), the compound C1 (23.30 g, 60 mmol), Pd(OAc).sub.2 (0.55 g, 2.49 mmol), S-Phos (2.04 g, 4.98 mmol), NaOt-Bu (8.6 g, 90.14 mmol) and o-xylene (500 ml) were mixed and heated at 185° C. for 4 hours. After cooling to room temperature, distilled water was added. The organic layer was extracted with ethyl acetate and distilled under reduced pressure. The obtained solid was separated by a column to obtain the compound Host2-1 (19.76 g, yield: 70.0%).

(85) 3. Synthesis of the Compound Host1-2

(86) (1) The Compound C2

(87) ##STR00015##

(88) In a flask, Mg (4.85 g, 200 mmol). THF (70 ml). I.sub.2 (0.19 g, 0.70 mmol) were mixed, and bromobenzene-D5 (32.4 g, 200 mmol) was slowly added. Thereafter, the mixture was heated to 75° C. and cooled to room temperature after 30 minutes. 2,4,6-trichloro-1,3,5-triazine (14.75 g, 80 mmol) was dissolved in THF (120 ml). After cooling to 0° C., the Grignard reagent prepared above was slowly added. After stirring at room temperature for 12 hours, an aqueous NH.sub.4Cl solution was added. The organic layer was extracted with ethyl acetate and residual moisture was removed using magnesium sulfate. Thereafter, the mixture was distilled under reduced pressure and separated by a column to obtain the compound C2 (14 g, yield: 63%).

(89) (2) The Compound A2

(90) ##STR00016##

(91) In a flask, the compound A1 (25 g, 91.45 mmol), 4-bromiodobenzene (51.58 g, 182.9 mmol), CuI (13.9 g, 73.16 mmol), toluene (1000 ml), Cs.sub.2CO.sub.3 (74.5 g, 228.6 mmol) and ethylenediamine (12.2 ml, 182.9 mmol) was added. It was heated to 155° C. and cooled to room temperature after 5 hours. Distilled water was added and the organic layer was extracted with ethyl acetate. After removing residual moisture using magnesium sulfate, the mixture was distilled under reduced pressure and separated by a column to obtain the compound A2 (18.5 g, yield: 47.23%).

(92) (3) The Compound A3

(93) ##STR00017##

(94) In a flask, the compound A2 (18.5 g, 43.18 mmol), 4,4,4',4',5,5,5',5'-octamethyl-2,2'-bi(1,3,2-dioxaborolane) (14.25 g, 56.14 mmol), PdCl.sub.2(PPh.sub.3) (1.5 g, 2.16 mmol), KOAc (8.5 g, 86.37 mmol), and 1,4-dioxane (800 ml) were added. The mixture was heated to 145° C. and cooled to room temperature after 4 hours. Distilled water was added and the organic layer was extracted

with ethyl acetate. After removing residual moisture using magnesium sulfate, the mixture was distilled under reduced pressure and separated by a column to obtain the compound A3 (14 g, yield: 68.22%).

(95) (4) The Compound Host1-2

(96) ##STR00018##

(97) In a flask, the compound A3 (14 g, 29.45 mmol), the compound C2 (8.9 g, 32.4 mmol), Pd(PPh.sub.3).sub.4 (1.7 g, 1.47 mmol). K.sub.2CO.sub.3 (8.1 g, 58.89 mmol), toluene (400 ml), distilled water (60 ml) and ethanol (40 ml) were added. The mixture was heated to 145° C. and cooled to room temperature after 5 hours. Distilled water was added and the organic layer was extracted with ethyl acetate. After removing residual moisture using magnesium sulfate, the mixture was distilled under reduced pressure and separated by a column to obtain the compound Host1-2 (10.5 g, yield: 60.3%).

(98) 4. Synthesis of the Compound Host1-3

(99) (1) 1-bromo-4-iodobenzene-d4

(100) ##STR00019##

(101) In a flask, 5-bromobenzene-d5 (36 g, 222.16 mmol), dichloromethane (216 ml), **12** (45 g, 177.7 mmol), acetic acid (CH.sub.3COOH, 108 ml) and sulfuric acid (H.sub.2SO.sub.4, 3.5 ml) were added and stirred for 10 minutes at 35° C. K.sub.2S.sub.2O.sub.8 (18.01 g, 66.65 mmol) was added to the mixture. The reaction temperature was heated to 45° C. and cooled to room temperature after 4 hours. The reaction solution was slowly added to the aqueous potassium carbonate solution. After neutralization, the organic layer was extracted with dichloromethane. The organic layer was again put into sodium thiosulfate aqueous solution and stirred. The organic layer was separated from the water layer. After removing residual moisture using magnesium sulfate, the mixture was dried and separated by a column to obtain 1-bromo-4-iodobenzene-d4 (27 g, yield: 42.8%).

(102) (2) The Compound A4

(103) ##STR00020##

(104) In a flask, the compound A1 (20 g, 73.16 mmol), 1-bromo-4-iodobenzene-d4 (27.29 g, 95.11 mmol), CuI (11.14 g, 58.53 mmol), toluene (700 ml), Cs.sub.2CO.sub.3 (59.59 g, 182.91 mmol) and ethylenediamine (9.8 ml, 146.3 mmol) was added. It was heated to 155° C. and cooled to room temperature after 19 hours. Distilled water was added and the organic layer was extracted with ethyl acetate. After removing residual moisture using magnesium sulfate, the mixture was distilled under reduced pressure and separated by a column to obtain the compound A4 (18.5 g, yield: 47.23%).

(105) (3) The Compound A5

(106) ##STR00021##

(107) In a flask, the compound A4 (23 g, 53.19 mmol), 4,4,4',4',5,5,5'-octamethyl-2,2'-bi(1,3,2-dioxaborolane) (17.5 g, 69.15 mmol), PdCl.sub.2(PPh.sub.3).sub.2 (1.86 g, 2.66 mmol), KOAc (10.46 g, 106.4 mmol), and 1,4-dioxane (900 ml) were added. The mixture was heated to 145° C. and cooled to room temperature after 5 hours. Distilled water was added and the organic layer was extracted with ethyl acetate. After removing residual moisture using magnesium sulfate, the mixture was distilled under reduced pressure and separated by a column to obtain the compound A5 (14 g, yield: 54.9%).

(108) (4) The Compound Host1-3

(109) ##STR00022##

(110) In a flask, the compound A5 (14 g, 29.20 mmol), the compound C2 (8.9 g, 32.12 mmol), Pd(PPh.sub.3).sub.4 (1.68 g, 1.46 mmol), K.sub.2CO.sub.3 (8.0 g, 58.40 mmol), toluene (400 ml), distilled water (60 ml) and ethanol (40 ml) were added. The mixture was refluxed and stirred and cooled to room temperature after 5 hours. Distilled water was added and the organic layer was extracted with ethyl acetate. After removing residual moisture using magnesium sulfate, the

mixture was distilled under reduced pressure and separated by a column to obtain the compound Host1-3 (10.5 g, yield: 60.45%).

(111) 5. Synthesis of the Compound Host1-4

(112) (1) The Compound A6

(113) ##STR00023##

(114) In a flask, the compound A1 (20.0 g, 9.0 mmol) and benzene-d6 (1.4 kg) were added and refluxed and stirred. Triflic acid (65.88 g, 438.9 mmol) was added at 70° C. After 5 hours, it was cooled to room temperature. D2O (40 ml) was mixed and stirred for 10 minutes. The mixture was neutralized with an aqueous K.sub.3PO.sub.4 solution, and the organic layer was extracted with ethyl acetate. After removing residual moisture using magnesium sulfate, the mixture was distilled under reduced pressure and separated by a column to obtain the compound A6 (15 g, yield: 72.99%).

(115) (2) The Compound Host1-4

(116) ##STR00024##

(117) In a flask, the compound A6 (14 g, 49.8 mmol), the compound C1 (23.21 g, 59.78 mmol), Pd(OAc).sub.2 (0.55 g, 2.49 mmol), S-Phos (2.04 g, 4.98 mmol), NaOt-Bu (8.6 g, 90.14 mmol) and o-xylene (500 ml) were mixed and heated at 185° C. for 4 hours. After cooling to room temperature, distilled water was added. The organic layer was extracted with ethyl acetate and distilled under reduced pressure. The obtained solid was separated by a column to obtain the compound Host1-4 (20.5 g, yield: 70.0%).

(118) 6. Synthesis of the Compound Host1-5

(119) (1) The Compound A7

(120) ##STR00025##

(121) In a flask, the compound A6 (20.8 g, 73.16 mmol), 1-bromo-4-iodobenzene-d4 (27.29 g, 95.11 mmol), CuI (11.14 g, 58.53 mmol), toluene (700 ml), Cs.sub.2CO.sub.3 (59.59 g, 182.91 mmol) and ethylenediamine (9.8 ml, 146.3 mmol) was added. It was heated to 155° C. and cooled to room temperature after 19 hours. Distilled water was added and the organic layer was extracted with ethyl acetate. After removing residual moisture using magnesium sulfate, the mixture was distilled under reduced pressure and separated by a column to obtain the compound A7 (19.1 g, yield: 47.23%).

(122) (2) The Compound A8

(123) ##STR00026##

(124) In a flask, the compound A7 (23.75 g, 53.19 mmol), 4,4,4',4',5,5,5',5'-octamethyl-2,2'-bi(1,3,2-dioxaborolane) (17.5 g, 69.15 mmol), PdCl.sub.2(PPh.sub.3).sub.2 (1.86 g, 2.66 mmol), KOAc (10.46 g, 106.4 mmol), and 1,4-dioxane (900 ml) were added. The mixture was heated to 145° C. and cooled to room temperature after 5 hours. Distilled water was added and the organic layer was extracted with ethyl acetate. After removing residual moisture using magnesium sulfate, the mixture was distilled under reduced pressure and separated by a column to obtain the compound A8 (14.4 g, yield: 54.9%).

(125) (3) The Compound Host1-5

(126) ##STR00027##

(127) In a flask, the compound A8 (14.4 g, 29.20 mmol), the compound C2 (8.9 g, 32.12 mmol), Pd(PPh.sub.3).sub.4 (1.68 g, 1.46 mmol), K.sub.2CO.sub.3 (8.0 g, 58.40 mmol), toluene (400 ml), distilled water (60 ml) and ethanol (40 ml) were added. The mixture was refluxed and heated and cooled to room temperature after 5 hours. Distilled water was added and the organic layer was extracted with ethyl acetate. After removing residual moisture using magnesium sulfate, the mixture was distilled under reduced pressure and separated by a column to obtain the compound Host1-5 (10.67 g, yield: 60.45%).

(128) 7. Synthesis of the Compound Host2-2

(129) (1) The Compound B2

(130) ##STR00028##

(131) In a flask, the compound B1 (18.8 g, 73.16 mmol), 1-bromo-4-iodobenzene (27.29 g, 96.47 mmol), CuI (11.14 g, 58.53 mmol), toluene (700 ml), Cs.sub.2CO.sub.3 (59.59 g, 182.91 mmol) and ethylenediamine (9.8 ml, 146.3 mmol) was added. It was heated to 155° C. and cooled to room temperature after 19 hours. Distilled water was added and the organic layer was extracted with ethyl acetate. After removing residual moisture using magnesium sulfate, the mixture was distilled under reduced pressure and separated by a column to obtain the compound B2 (17.8 g, yield: 47.23%).

(132) (2) The Compound B3

(133) ##STR00029##

(134) In a flask, the compound B2 (17.8 g, 43.18 mmol), 4,4,4',5,5,5'-octamethyl-2,2'-bi(1,3,2-dioxaborolane) (14.25 g, 56.14 mmol), PdCl.sub.2 (PPh.sub.3) (1.5 g, 2.16 mmol), KOAc (8.5 g, 86.37 mmol), and 1,4-dioxane (800 ml) were added. The mixture was heated to 145° C. and cooled to room temperature after 4 hours. Distilled water was added and the organic layer was extracted with ethyl acetate. After removing residual moisture using magnesium sulfate, the mixture was distilled under reduced pressure and separated by a column to obtain the compound B3 (13.53 g, yield: 68.22%).

(135) (3) The Compound Host2-2

(136) ##STR00030##

(137) In a flask, the compound B3 (13.52 g, 29.45 mmol), the compound C2 (8.9 g, 32.4 mmol), Pd(PPh.sub.3).sub.4 (1.7 g, 1.47 mmol), K.sub.2CO.sub.3 (8.1 g, 58.89 mmol), toluene (400 ml), distilled water (60 ml) and ethanol (40 ml) were added. The mixture was heated to 145° C. and cooled to room temperature after 5 hours. Distilled water was added and the organic layer was extracted with ethyl acetate. After removing residual moisture using magnesium sulfate, the mixture was distilled under reduced pressure and separated by a column to obtain the compound Host2-2 (10.21 g, yield: 60.3%).

(138) 8. Synthesis of the Compound Host2-3

(139) (1) the Compound B4

(140) ##STR00031##

(141) In a flask, the compound B1 (18.81 g, 73.16 mmol), 1-bromo-4-iodobenzene-d4 (27.29 g, 95.11 mmol), CuI (11.14 g, 58.53 mmol), toluene (700 ml), Cs.sub.2CO.sub.3 (59.59 g, 182.91 mmol) and ethylenediamine (9.8 ml, 146.3 mmol) was added. It was heated to 155° C. and cooled to room temperature after 19 hours. Distilled water was added and the organic layer was extracted with ethyl acetate. After removing residual moisture using magnesium sulfate, the mixture was distilled under reduced pressure and separated by a column to obtain the compound B4 (17.81 g, yield: 47.23%).

(142) (2) The Compound B5

(143) ##STR00032##

(144) In a flask, the compound B4 (22.14 g, 53.19 mmol), 4,4,4',4',5,5,5'5'-octamethyl-2,2'-bi(1,3,2-dioxaborolane) (17.5 g, 69.15 mmol). PdCl.sub.2(PPh.sub.3).sub.2 (1.86 g, 2.66 mmol), KOAc (10.46 g, 106.4 mmol), and 1,4-dioxane (900 ml) were added. The mixture was heated to 145° C. and cooled to room temperature after 5 hours. Distilled water was added and the organic layer was extracted with ethyl acetate. After removing residual moisture using magnesium sulfate, the mixture was distilled under reduced pressure and separated by a column to obtain the compound B5 (13.53 g, yield: 54.9%).

(145) (3) The Compound Host2-3

(146) ##STR00033##

(147) In a flask, the compound B5 (13.53 g, 29.20 mmol), the compound C2 (8.9 g, 32.12 mmol), Pd(PPh.sub.3).sub.4 (1.68 g, 1.46 mmol), K.sub.2CO.sub.3 (8.0 g, 58.40 mmol), toluene (400 ml), distilled water (60 ml) and ethanol (40 ml) were added. The mixture was refluxed and stirred and

cooled to room temperature after 5 hours. Distilled water was added and the organic layer was extracted with ethyl acetate. After removing residual moisture using magnesium sulfate, the mixture was distilled under reduced pressure and separated by a column to obtain the compound Host2-3 (10.2 g, yield: 60.45%).

(148) 9. Synthesis of the Compound Host2-4

(149) (1) The Compound B6

(150) ##STR00034##

(151) In a flask, the compound B1 (18.8 g, 9.0 mmol) and benzene-d₆ (1.4 kg) were added and refluxed and stirred. Triflic acid (65.88 g, 438.9 mmol) was added at 70° C. After 5 hours, it was cooled to room temperature. D.sub.2O (40 ml) was mixed and stirred for 10 minutes. The mixture was neutralized with an aqueous K.sub.3PO.sub.4 solution, and the organic layer was extracted with ethyl acetate. After removing residual moisture using magnesium sulfate, the mixture was distilled under reduced pressure and separated by a column to obtain the compound B6 (14.15 g, yield: 72.99%).

(152) (2) The Compound Host2-4

(153) ##STR00035##

(154) In a flask, the compound B6 (13.20 g, 49.8 mmol), the compound C1 (23.21 g, 59.78 mmol), Pd(OAc).sub.2 (0.55 g, 2.49 mmol), S-Phos (2.04 g, 4.98 mmol), NaOt-Bu (8.6 g, 90.14 mmol) and o-xylene (500 ml) were mixed and heated at 185° C. for 4 hours. After cooling to room temperature, distilled water was added. The organic layer was extracted with ethyl acetate and distilled under reduced pressure. The obtained solid was separated by a column to obtain the compound Host2-4 (19.9 g, yield: 70.0%).

(155) 10. Synthesis of the Compound Host2-5

(156) (1) The Compound B7

(157) ##STR00036##

(158) In a flask, the compound B6 (19.6 g, 73.16 mmol), 1-bromo-4-iodobenzene-d₄ (27.29 g, 95.11 mmol), CuI (11.14 g, 58.53 mmol), toluene (700 ml), Cs.sub.2CO.sub.3 (59.59 g, 182.91 mmol) and ethylenediamine (9.8 ml, 146.3 mmol) was added. It was heated to 155° C. and cooled to room temperature after 19 hours. Distilled water was added and the organic layer was extracted with ethyl acetate. After removing residual moisture using magnesium sulfate, the mixture was distilled under reduced pressure and separated by a column to obtain the compound B7 (18.4 g, yield: 47.23%).

(159) (2) The Compound B8

(160) ##STR00037##

(161) In a flask, the compound B7 (22.88 g, 53.19 mmol), 4,4,4',4',5,5,5',5'-octamethyl-2,2'-bi(1,3,2-dioxaborolane) (17.5 g, 69.15 mmol), PdCl.sub.2(PPh.sub.3).sub.2 (1.86 g, 2.66 mmol), KOAc (10.46 g, 106.4 mmol), and 1,4-dioxane (900 ml) were added. The mixture was heated to 145° C. and cooled to room temperature after 5 hours. Distilled water was added and the organic layer was extracted with ethyl acetate. After removing residual moisture using magnesium sulfate, the mixture was distilled under reduced pressure and separated by a column to obtain the compound B8 (13.9 g, yield: 54.9%).

(162) (3) The Compound Host2-5

(163) ##STR00038##

(164) In a flask, the compound B8 (13.9 g, 29.20 mmol), the compound C2 (8.9 g, 32.12 mmol), Pd(PPh.sub.3).sub.4 (1.68 g, 1.46 mmol), K.sub.2CO.sub.3 (8.0 g, 58.40 mmol), toluene (400 ml), distilled water (60 ml) and ethanol (40 ml) were added. The mixture was refluxed and heated and cooled to room temperature after 5 hours. Distilled water was added and the organic layer was extracted with ethyl acetate. After removing residual moisture using magnesium sulfate, the mixture was distilled under reduced pressure and separated by a column to obtain the compound Host2-5 (10.39 g, yield: 60.45%).

(165) 11. Synthesis of the Compound Host3-2

(166) (1) 3-bromobiphenyl-d9

(167) ##STR00039##

(168) In a flask, 3-bromobiphenyl (21.0 g, 9.0 mmol) and benzene-d6 (1.4 kg) were added and refluxed and stirred. Triflic acid (65.88 g, 438.9 mmol) was added at 70° C. After 5 hours, it was cooled to room temperature. D2O (40 ml) was mixed and stirred for 10 minutes. The mixture was neutralized with an aqueous K.sub.3PO.sub.4 solution, and the organic layer was extracted with ethyl acetate. After removing residual moisture using magnesium sulfate, the mixture was distilled under reduced pressure and separated by a column to obtain 3-bromobiphenyl-d9 (15.92 g, yield: 72.99%).

(169) (2) The Compound Host3-2

(170) ##STR00040##

(171) In a flask, 3,3'-biscarbazole (16.55 g, 49.8 mmol), 3-bromobiphenyl-d9 (26.63 g, 110 mmol), Pd(OAc).sub.2 (0.55 g, 2.49 mmol), S-Phos (2.04 g, 4.98 mmol), NaOt-Bu (10.5 g, 90.14 mmol) and o-xylene (500 ml) were mixed and heated at 185° C. for 4 hours. After cooling to room temperature, distilled water was added. The organic layer was extracted with ethyl acetate and distilled under reduced pressure. The obtained solid was separated by a column to obtain the compound Host3-2 (22.82 g, yield: 70.0%).

(172) 12. Synthesis of the Compound Host3-3

(173) (1) 3,3'-Biscarbazole-d14

(174) ##STR00041##

(175) In a flask, 3,3'-biscarbazole (29.9 g, 90 mmol) and benzene-d6 (1.4 kg) were added and refluxed and stirred. Triflic acid (65.88 g, 438.9 mmol) was added at 70° C. After 5 hours, it was cooled to room temperature. D2O (40 ml) was mixed and stirred for 10 minutes. The mixture was neutralized with an aqueous K.sub.3PO.sub.4 solution, and the organic layer was extracted with ethyl acetate. After removing residual moisture using magnesium sulfate, the mixture was distilled under reduced pressure and separated by a column to obtain 3,3'-biscarbazole-d14 (22.76 g, yield: 72.99%).

(176) (2) The Compound Host3-3

(177) ##STR00042##

(178) In a flask, 3,3'-biscarbazole-d14 (17.25 g, 49.8 mmol), 3-bromobiphenyl (25.64 g, 110 mmol), Pd(OAc).sub.2 (0.55 g, 2.49 mmol), S-Phos (2.04 g, 4.98 mmol), NaOt-Bu (10.5 g, 90.14 mmol) and o-xylene (500 ml) were mixed and heated at 185° C. for 4 hours. After cooling to room temperature, distilled water was added. The organic layer was extracted with ethyl acetate and distilled under reduced pressure. The obtained solid was separated by a column to obtain the compound Host3-3 (22.69 g, yield: 70.0%).

(179) 13. Synthesis of the Compound Host3-4

(180) ##STR00043##

(181) In a flask, the compound Host3-1 (15.0 g, 42.9 mmol) and benzene-d6 (900 ml) were added and heated. Triflic acid (25.4 g, 169.5 mmol) was added at 70° C. After 3 hours, it was cooled to room temperature. D2O (30 ml) was mixed and stirred for 10 minutes. The mixture was neutralized with an aqueous K.sub.3PO.sub.4 solution, and the organic layer was extracted with ethyl acetate. After removing residual moisture using magnesium sulfate, the mixture was distilled under reduced pressure and separated by a column to obtain the compound Host3-4 (12 g, yield: 77.0%).

(182) The green EML **230** can further include a dopant, e.g., an emitter, **236**. In the green EML **230**, a weight % of each of the first host **232** and the second host **234** can be greater than that of the dopant **236**. The dopant **236** can be one of a phosphorescent compound, a fluorescent compound and a delayed fluorescent compound and can have a weight % of 3 weight % to 30 weight % in the green EML **230**, preferably 5 weight % to 15 weight %.

(183) The dopant **236** in the green EML **230** can be an iridium complex and can be represented by

Formula 5.

(184) ##STR00044##

(185) In Formula 5, each of R.sub.161 to R.sub.164 is independently selected from the group consisting of deuterium, halogen atom, C1 to C6 alkyl group, C3 to C6 cycloalkyl group, C6 to C10 aryl group and C3 to C10 heteroaryl group. Each of t, v and w is independently an integer of 0 to 4, and u is an integer of 0 to 3. X is oxygen atom or sulfur atom. Each of Z.sub.1 to Z.sub.4 is independently nitrogen or CR.sub.165, and R.sub.165 is selected from hydrogen, deuterium, halogen atom, C1 to C6 alkyl group, C3 to C6 cycloalkyl group, C6 to C10 aryl group and C3 to C10 heteroaryl group. (t, u, v and w are the number of substituents)

(186) In the present disclosure, aryl group can be selected from the group consisting of phenyl group, biphenyl group, terphenyl group, naphthyl group, anthracenyl group, pentalenyl group, indenyl group, indenoindenyl group, heptalenyl group, biphenylenyl group, indacenyl group, phenalenyl group, phenanthrenyl group, benzophenanthrenyl group, dibenzophenanthrenyl group, azulenyl group, pyrenyl group, fluoranthenyl group, triphenylenyl group, chrysenyl group, tetraphenyl group, tetracenyl group, pleiadenyl group, picenyl group, pentaphenyl group, pentacenyl group, fluorenyl group, indenofluorenyl group, and spiro-fluorenyl group without specific definition. The above definition of the aryl group can be applied to arylene group, except that arylene group is a divalent group.

(187) In the present disclosure, heteroaryl group can be selected from the group consisting of pyrrolyl group, pyridinyl group, pyrimidinyl group, pyrazinyl group, pyridazinyl group, triazinyl group, tetrazinyl group, imidazolyl group, pyrazolyl group, indolyl group, isoindolyl group, indazolyl group, indolizinyl group, pyrrolizinyl group, carbazolyl group, benzocarbazolyl group, dibenzocarbazolyl group, indolocarbazolyl group, indenocarbazolyl group, benzofurocarbazolyl group, benzothienocarbazolyl group, quinolinyl group, isoquinolinyl group, phthalazinyl group, quinoxalinyl group, cinnolinyl group, quinazolinyl group, quinolizinyl group, purinyl group, benzoquinolinyl group, benzoisoquinolinyl group, benzoquinazolinyl group, benzoquinoxalinyl group, acridinyl group, phenanthrolinyl group, perimidinyl group, phenanthridinyl group, pteridinyl group, cinnolinyl group, naphtharidinyl group, furanyl group, pyranyl group, oxazinyl group, oxazolyl group, oxadiazolyl group, triazolyl group, dioxinyl group, benzofuranyl group, dibenzofuranyl group, thiopyranyl group, xanthenyl group, chromaenyl group, isochromenyl group, thioazinyl group, thiophenyl group, benzothiophenyl group, dibenzothiophenyl group, difuropyrazinyl group, benzofurodibenzofuranyl group, benzothienobenzothiophenyl group, benzothienodibenzothiophenyl group, benzothienobenzofuranyl group, and benzothienodibenzofuranyl group without specific definition. The above definition of the heteroaryl group can be applied to heteroarylene group, except that heteroarylene group is a divalent group.

(188) The dopant **236** in the green EML **230** can be one of the compounds in Formula 6.

(189) ##STR00045##

(190) The HIL **210** can include a compound in Formula 7-1 as a hole injection material.

(191) ##STR00046##

(192) In Formula 7-1, each of R.sub.61 and R.sub.62 is independently selected from the group consisting of C6 to C30 aryl group and C3 to C30 heteroaryl group, and each of R.sub.63 and R.sub.64 is independently C1 to C20 alkyl group. Each of f and g is a number of substituent and is independently an integer of 0 to 4. Each of L.sub.1 and L.sub.2 is independently C6 to C30 arylene group, and each of h and i is 0 or 1.

(193) For example, each of the aryl group, the heteroaryl group and the arylene group can be unsubstituted or substituted with at least one of C1 to C10 alkyl and C6 to C20 aryl.

(194) For example, in Formula 7-1, each of L.sub.1 and L.sub.2 can be phenylene unsubstituted or substituted with C1 to C10 alkyl or C6 to C20 aryl. e.g., phenyl, and each of R.sub.61 and R.sub.62 can be independently selected from the group consisting of phenyl, naphthyl, fluorenyl,

dibenzofuranyl and carbazoyl, each of which can be unsubstituted or substituted with C1 to C10 alkyl or C6 to C30 aryl, e.g., phenyl.

(195) In Formula 7-1, f, g, h and i can be 0 (zero), R.sub.61 can be biphenyl, and R.sub.62 can be dimethyl-substituted fluorenyl. Namely, the compound in Formula 7-1 can be represented by Formula 7-2.

(196) ##STR00047##

(197) For example, the compound in Formula 7-1 can be one of the compounds in Formula 8, but it is not limited thereto.

(198) ##STR00048## ##STR00049## ##STR00050## ##STR00051## ##STR00052##
##STR00053## ##STR00054##

(199) For example, the HIL **210** can further include a compound having a radialene structure in Formula 9 as a dopant, e.g., a p-type dopant.

(200) ##STR00055##

(201) For example, in the HIL **210**, the dopant can have a weight % of 0.1 weight % to 20 weight %, preferably 5 weight % to 15 weight %. The HIL **210** can have a thickness of 10 to 200 Å, preferably 30 to 100 Å.

(202) The HTL **220** can include the compound in Formula 7-1 as a hole transporting material. For example, the HTL **220** can have a thickness of 50 to 400 Å, preferably 150 to 300 Å.

(203) The hole injection material in the HIL **210** and the hole transporting material in the HTL **220** can be a compound having the same structure, e.g., the same compound. In this instance, the interfacial property between the HIL **210** and the HTL **220** is improved such that the emitting efficiency and the lifespan of the OLED can be further increased.

(204) The ETL **240** can have a thickness of 50 to 400 Å. The ETL **240** can include a compound in Formula 10 as an electron transporting material, e.g., a first electron transporting material.

(205) ##STR00056##

(206) In Formula 10, Ar is C10 to C30 arylene group, and R.sub.81 is C6 to C30 aryl group or C5 to C30 heteroaryl group, each of the C6 to C30 aryl group and the C5 to C30 heteroaryl group is optionally substituted with C1 to C10 alkyl group. Each of R.sub.82 and R.sub.83 is independently hydrogen, C1 to C10 alkyl group or C6 to C30 aryl group.

(207) In Formula 10, Ar can be naphthylene or anthracenylene, and R.sub.81 can be phenyl unsubstituted or substituted with C1 to C10 alkyl, or benzimidazole group. R.sub.82 can be methyl, ethyl or phenyl, and R.sub.83 can be hydrogen, a methyl group or a phenyl group.

(208) For example, the compound in Formula 10 can be one of the compounds in Formula 11.

(209) ##STR00057##

(210) Alternatively, the ETL **240** can include a compound in Formula 12 as an electron transporting material, e.g., a second electron transporting material.

(211) ##STR00058##

(212) In Formula 12, each of Y.sub.1 to Y.sub.5 is independently CR.sub.71 or nitrogen atom (N), and one to three of Y.sub.1 to Y.sub.5 is N. R.sub.71 is hydrogen or C6 to C30 aryl group, and L is C6 to C30 arylene group. Each of R.sub.72 and R.sub.73 is independently selected from the group consisting of hydrogen, and C5 to C30 heteroaryl group, and at least one of R.sub.72 and R.sub.73 is C5 to C30 heteroaryl group. In addition, a is 0 or 1.

(213) In Formula 12, one or two of Y.sub.1 to Y.sub.5 can be N. The heteroaryl group for R.sub.72 and R.sub.73 can be carbazoyl, and L can be phenylene.

(214) For example, the compound in Formula 12 can be one of the compounds in Formula 13.

(215) ##STR00059## ##STR00060## ##STR00061## ##STR00062## ##STR00063##

(216) The ETL **240** can include both the compound in Formula 10 and the compound in Formula 12. In this instance, the compound in Formula 10 and the compound in Formula 12 can have the same weight %.

(217) The EIL **250** can have a thickness of 10 to 400 Å, preferably 100 to 300 Å.

(218) The EIL **250** can include a compound in Formula 14 as an electron injection material.

(219) ##STR00064##

(220) In Formula 14, R.sub.91 is hydrogen or C6 to C30 aryl group, and R.sub.92 is C6 to C30 aryl group or C5 to C30 heteroaryl group. The C6 to C30 aryl group or C5 to C30 heteroaryl group can be unsubstituted or substituted. L.sub.4 is C6 to C30 arylene group or C5 to C30 heteroarylene group, and m is 1 or 2.

(221) In this instance, the aryl group, the arylene group and the heteroarylene group can be unsubstituted or substituted with C1 to C10 alkyl.

(222) For example, in Formula 14, R.sub.91 can be hydrogen, phenyl unsubstituted or substituted with methyl, or naphthyl unsubstituted or substituted with methyl, and R.sub.92 can be phenyl unsubstituted or substituted with methyl, naphthyl unsubstituted or substituted with methyl or phenanthrenyl unsubstituted or substituted with methyl. L.sub.4 can be phenylene, naphthylene, anthracenylene or phenanthrenylene.

(223) The compound in Formula 14 can be one of the compounds in Formula 15.

(224) ##STR00065## ##STR00066##

(225) The EIL **250** can further include a dopant being one of alkali metal, e.g., Li, Na, K or Cs, and alkali earth metal, e.g., Mg, Sr, Ba or Ra. In this instance, the electron injection property of the EIL **250** can be improved. In the EIL **250**, the dopant can have a weight % of 0.1 weight % to 10 weight %, preferably 0.5 weight % to 5 weight %.

(226) The EBL can include at least one of tris(4-carbazoyl-9-yl-phenyl)amine (TCTA), tris[4-(diethylamino)phenyl]amine, N-(biphenyl-4-yl)-9,9-dimethyl-N-(4-(9-phenyl-9H-carbazol-3-yl)phenyl)-9H-fluoren-2-amine, TAPC, 4,4',4''-tris(3-methylphenylamino)triphenylamine (MTDATA), 1,3-bis(carbazol-9-yl)benzene (mCP), 3,3'-bis(N-carbazolyl)-1,1'-biphenyl (mCBP), copper phthalocyanine (CuPc), N,N'-bis[4-[bis(3-methylphenyl)amino]phenyl]-N,N'-diphenyl-[1,1'-biphenyl]-4,4'-diamine (DNTPD), 1,3,5-tris[4-(diphenylamino)phenyl]benzene (TDAPB), DCDPA, and 2,8-bis(9-phenyl-9H-carbazol-3-yl)dibenzo[b,d]thiophene), but it is not limited thereto. For example, the EBL can have a thickness of 10 to 350 Å, preferably 100 to 200 Å.

(227) Alternatively, the EBL can include a compound in Formula 16 as an electron blocking material

(228) ##STR00067##

(229) In Formula 16, L is C6 to C30 arylene group, and a is 0 or 1. Each of R.sub.1 and R.sub.2 is independently selected from the group consisting of C6 to C30 aryl group and C5 to C30 heteroaryl group, wherein each of the C6 to C30 aryl group and C5 to C30 heteroaryl group is optionally substituted with at least one of C1 to C10 alkyl group and C6 to C30 aryl group, respectively.

(230) For example, L can be phenylene, and each of R.sub.1 and R.sub.2 can be independently selected from the group consisting of biphenyl, dimethyl-substituted fluorenyl, phenylcarbazolyl, carbazolylphenyl, dibenzothiophenyl and dibenzofuranyl.

(231) Namely, the electron blocking material in Formula 16 is an amine derivative substituted with spirofluorene (e.g., spirofluorene-substituted amine derivative).

(232) The electron blocking material in Formula 16 can be one of the compounds in Formula 17.

(233) ##STR00068## ##STR00069## ##STR00070## ##STR00071##

(234) The HBL can include at least one of tris-(8-hydroxyquinoline) aluminum (Alq.sub.3), 2-biphenyl-4-yl-5-(4-t-butylphenyl)-1,3,4-oxadiazole (PBD), spiro-PBD, lithium quinolate (Liq), 2,2',2''-(1,3,5-Benzenetriyl)-tris(1-phenyl-1-H benzimidazole) (TPBi), bis(2-methyl-8-quinolinolato-N1,O8)-(1,1'-biphenyl-4-olato)aluminum (BALq), 4,7-diphenyl-1,10-phenanthroline (Bphen), 2,9-bis(naphthalene-2-yl)4,7-diphenyl-1,10-phenanthroline (NBphen), 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP), 3-(4-biphenyl)-4-phenyl-5-tert-butylphenyl-1,2,4-triazole (TAZ), 4-(naphthalen-1-yl)-3,5-diphenyl-4H-1,2,4-triazole (NTAZ), 1,3,5-tri(p-pyrid-3-yl-phenyl)benzene (TpPVPB), 2,4,6-tris(3'-(pyridin-3-yl)biphenyl-3-yl)1,3,5-triazine (TmPPPyTz), Poly[9,9-bis(3'-((N,N-dimethyl)-N-ethylammonium)-propyl)-2,7-fluorene-alt-2,7-(9,9-

diocetylfluorene)] (PFNBr), tris(phenylquinoxaline) (TPQ), and diphenyl-4-triphenylsilyl-phenylphosphine oxide (TSPO1), but it is not limited thereto. For example, the HBL can have a thickness of 10 to 350 Å, preferably 100 to 200 Å.

(235) As described above, in the OLED D disposed in the green pixel region, the green EML **230** includes the first host **232** having a fused-hetero ring moiety and a second host **234** having a biscarbazole moiety, and at least one of the fused-hetero ring moiety of the first host **232** and the biscarbazole moiety of the second host **234** is partially or wholly deuterated. As a result, the lifespan of the OLED D and the organic light emitting display device **100** including the OLED D is significantly increased.

(236) In addition, when only the fused-hetero ring moiety in the first host **232** is deuterated and/or only the biscarbazole moiety in the second host **234** is deuterated, the emitting efficiency and the lifespan of the OLED D and the organic light emitting display device **100** are further improved.

(237) [Organic Light Emitting Diode]

(238) On the anode (ITO), the HIL (the compound E3 in Formula 8 and the compound 11 in Formula 9 (10 wt %), 50 Å), the HTL (the compound E3 in Formula 8, 250 Å), the green EML (a first host, a second host and a dopant (the compound S1 in Formula 6, 12 wt %), 300 Å), the ETL (the compound G1 in Formula 11, 200 Å), the EIL (the compound H1 in Formula 15 and L.sub.1 (2 wt %), 200 Å), and the cathode (AgMg (weight ratio=10:1)) was sequentially deposited. An encapsulation film is formed by using an UV curable epoxy and a moisture getter to form the OLED.

1. Comparative Example

(1) Comparative Example 1 (Ref1)

(239) In the green EML, the compound Host1-1 in Formula 3 and the compound Host3-1 in Formula 4 are used as the first host and the second host, respectively. (the first host:the second host=3:7 (weight ratio))

(2) Comparative Example 2 (Ref2)

(240) In the green EML, the compound Host2-1 in Formula 3 and the compound Host3-1 in Formula 4 are used as the first host and the second host, respectively. (the first host:the second host=3:7 (weight ratio))

2. Example

(1) Examples 1 to 4 (Ex1 to Ex4)

(241) In the green EML, the compound Host3-1 in Formula 4 is used as the second host, and the compounds Host1-2, Host1-3, Host1-4 and Host1-5 in Formula 3 are used as the first host. (the first host:the second host=3:7 (weight ratio))

(2) Examples 5 to 8 (Ex5 to Ex8)

(242) In the green EML, the compound Host3-1 in Formula 4 is used as the second host, and the compounds Host2-2, Host2-3, Host2-4 and Host2-5 in Formula 3 are used as the first host. (the first host:the second host=3:7 (weight ratio))

(3) Examples 9 to 13 (Ex9 to Ex13)

(243) In the green EML, the compound Host3-2 in Formula 4 is used as the second host, and the compounds Host1-1, Host1-2, Host1-3, Host1-4 and Host1-5 in Formula 3 are used as the first host. (the first host:the second host=3:7 (weight ratio))

(4) Examples 14 to 18 (Ex14 to Ex18)

(244) In the green EML, the compound Host3-2 in Formula 4 is used as the second host, and the compounds Host2-1, Host2-2, Host2-3, Host2-4 and Host2-5 in Formula 3 are used as the first host. (the first host:the second host=3:7 (weight ratio))

(5) Examples 19 to 23 (Ex19 to Ex23)

(245) In the green EML, the compound Host3-3 in Formula 4 is used as the second host, and the compounds Host1-1, Host1-2, Host1-3, Host1-4 and Host1-5 in Formula 3 are used as the first host. (the first host:the second host=3:7 (weight ratio))

(6) Examples 24 to 28 (Ex24 to Ex28)

(246) In the green EML, the compound Host3-3 in Formula 4 is used as the second host, and the compounds Host2-1, Host2-2, Host2-3, Host2-4 and Host2-5 in Formula 3 are used as the first host. (the first host:the second host=3:7 (weight ratio))

(7) Examples 29 to 33 (Ex29 to Ex33)

(247) In the green EML, the compound Host3-4 in Formula 4 is used as the second host, and the compounds Host1-1, Host1-2, Host1-3, Host1-4 and Host1-5 in Formula 3 are used as the first host. (the first host:the second host=3:7 (weight ratio))

(8) Examples 34 to 38 (Ex34 to Ex38)

(248) In the green EML, the compound Host3-4 in Formula 4 is used as the second host, and the compounds Host2-1, Host2-2, Host2-3, Host2-4 and Host2-5 in Formula 3 are used as the first host. (the first host:the second host=3:7 (weight ratio))

(249) The properties, e.g., the driving voltage (V), the efficiency (cd/A), the lifespan (hr) and the color coordinate, of the OLED of Ref1 and Ref2 and Ex1 to Ex38 are measured and listed in Tables 1 to 3. The driving voltage and the efficiency were measured at a current density of 10 mA/cm², and the lifespan is the time until a luminance of 95% of the initial luminance is achieved at a current density of 22.5 mA/cm² and a temperature condition of 40° C.

(250) TABLE-US-00001 TABLE 1 G-EML lifespan Host 2 Host 1 V cd/A (hr) CIE_x CIE_y Ref 1
Host 3-1 Host 1-1 3.15 79.01 145 0.356 0.619 Ex 1 Host 3-1 Host 1-2 3.15 79.01 160 0.356 0.619
Ex 2 Host 3-1 Host 1-3 3.15 79.01 161 0.356 0.619 Ex 3 Host 3-1 Host 1-4 3.15 78.93 189 0.356
0.619 Ex 4 Host 3-1 Host 1-5 3.15 78.85 184 0.356 0.619 Ref 2 Host 3-1 Host 2-1 3.45 75.06 138
0.356 0.619 Ex 5 Host 3-1 Host 2-2 3.45 74.98 152 0.356 0.619 Ex 6 Host 3-1 Host 2-3 3.45
74.98 152 0.356 0.619 Ex 7 Host 3-1 Host 2-4 3.45 74.98 181 0.356 0.619 Ex 8 Host 3-1 Host 2-
5 3.45 74.98 177 0.356 0.619 Ex 9 Host 3-2 Host 1-1 3.15 79.01 167 0.356 0.619 Ex 10 Host 3-2
Host 1-2 3.15 79.01 184 0.356 0.619 Ex 11 Host 3-2 Host 1-3 3.15 79.01 184 0.356 0.619 Ex 12
Host 3-2 Host 1-4 3.15 78.93 217 0.356 0.619 Ex 13 Host 3-2 Host 1-5 3.15 78.85 207 0.356 0.619

(251) TABLE-US-00002 TABLE 2 G-EML lifespan Host 2 Host 1 V cd/A (hr) CIE_x CIE_y Ex 14
Host 3-2 Host 2-1 3.45 75.06 159 0.356 0.619 Ex 15 Host 3-2 Host 2-2 3.45 74.98 173 0.356 0.619
Ex 16 Host 3-2 Host 2-3 3.45 74.98 174 0.356 0.619 Ex 17 Host 3-2 Host 2-4 3.45 74.98 209 0.356
0.619 Ex 18 Host 3-2 Host 2-5 3.45 74.98 202 0.356 0.619 Ex 19 Host 3-3 Host 1-1 3.15 79.01 175
0.356 0.619 Ex 20 Host 3-3 Host 1-2 3.15 79.01 191 0.356 0.619 Ex 21 Host 3-3 Host 1-3 3.15
79.01 191 0.356 0.619 Ex 22 Host 3-3 Host 1-4 3.15 78.93 225 0.356 0.619 Ex 23 Host 3-3 Host 1-
5 3.15 78.85 216 0.356 0.619 Ex 24 Host 3-3 Host 2-1 3.45 75.06 165 0.356 0.619 Ex 25 Host 3-3
Host 2-2 3.45 74.98 181 0.356 0.619 Ex 26 Host 3-3 Host 2-3 3.45 74.98 181 0.356 0.619 Ex 27
Host 3-3 Host 2-4 3.45 74.98 218 0.356 0.619 Ex 28 Host 3-3 Host 2-5 3.45 74.98 210 0.356 0.619

(252) TABLE-US-00003 TABLE 3 G-EML lifespan Host 2 Host 1 V cd/A (hr) CIE_x CIE_y Ex 29
Host 3-4 Host 1-1 3.15 79.01 189 0.356 0.619 Ex 30 Host 3-4 Host 1-2 3.15 79.01 206 0.356 0.619
Ex 31 Host 3-4 Host 1-3 3.15 79.01 207 0.356 0.619 Ex 32 Host 3-4 Host 1-4 3.15 78.93 247 0.356
0.619 Ex 33 Host 3-4 Host 1-5 3.15 78.85 235 0.356 0.619 Ex 34 Host 3-4 Host 2-1 3.45 75.06 178
0.356 0.619 Ex 35 Host 3-4 Host 2-2 3.45 74.98 197 0.356 0.619 Ex 36 Host 3-4 Host 2-3 3.45
74.98 197 0.356 0.619 Ex 37 Host 3-4 Host 2-4 3.45 74.98 236 0.356 0.619 Ex 38 Host 3-4 Host 2-
5 3.45 74.98 231 0.356 0.619

(253) As shown in Tables 1 to 3, in comparison to the OLED of Ref1 and Ref2, in which the first and second hosts are not deuterated, the lifespan of the OLED of Ex1 to Ex38, in which at least one of the first and second hosts is deuterated, is significantly increased.

(254) In addition, in the OLED of Ex3, Ex7, Ex12, Ex17, Ex22, Ex27, Ex32 and Ex37, in which the fused-hetero ring moiety of the first host is deuterated, and Ex19 to Ex28, in which the biscarbazole moiety of the second host is deuterated, the lifespan is further increased.

(255) Namely, in comparison to the OLED using the first host, i.e., the compounds Host1-2, Host1-3, Host2-2 and Host2-3, in which the phenylene linker and/or the triazine moiety except the fused-

hetero ring moiety is deuterated, the lifespan of the OLED using the first host, i.e., the compounds Host1-4 and Host2-4, in which only the fused-hetero ring moiety is deuterated, is improved. In addition, in comparison to the OLED using the second host, i.e., the compound Host3-2, in which the biphenyl moiety except the biscarbazole moiety is deuterated, the lifespan of the OLED using the second host, i.e., the compound Host3-3, in which only the biscarbazole moiety is deuterated, is improved.

(256) Moreover, in comparison to the OLED using the first host, i.e., the compounds Host1-5 and Host2-5, which is wholly deuterated, the lifespan of the OLED using the first host, i.e., the compounds Host1-4 and Host2-4, in which only the fused-hetero ring moiety is deuterated, is improved. Accordingly, without additional increase of the production cost by the deuterium atom, the OLED has an advantage of increase of the lifespan.

(257) FIG. 4 is a schematic cross-sectional view illustrating an organic light emitting display device according to a third embodiment of the present disclosure. FIG. 5 is a schematic cross-sectional view illustrating an OLED according to a fourth embodiment of the present disclosure, and FIG. 6 is a schematic cross-sectional view illustrating an OLED according to a fifth embodiment.

(258) As shown in FIG. 4, the organic light emitting display device **300** includes a first substrate **310**, where a red pixel region RP, a green pixel region GP and a blue pixel region BP are defined, a second substrate **370** facing the first substrate **310**, an OLED D, which is positioned between the first and second substrates **310** and **370** and providing white emission, and a color filter layer **380** between the OLED D and the second substrate **370**.

(259) Each of the first and second substrates **310** and **370** can be a glass substrate or a flexible substrate. For example, the flexible substrate can be a polyimide (PI) substrate, a polyethersulfone (PES) substrate, a polyethylenenaphthalate (PEN) substrate, a polyethylene terephthalate (PET) substrate or a polycarbonate (PC) substrate.

(260) A buffer layer **320** is formed on the first substrate **310**, and the TFT Tr corresponding to each of the red, green and blue pixel regions RP, GP and BP is formed on the buffer layer **320**. The buffer layer **320** can be omitted.

(261) A semiconductor layer **322** is formed on the buffer layer **320**. The semiconductor layer **322** can include an oxide semiconductor material or polycrystalline silicon.

(262) A gate insulating layer **324** is formed on the semiconductor layer **322**. The gate insulating layer **324** can be formed of an inorganic insulating material such as silicon oxide or silicon nitride.

(263) A gate electrode **330**, which is formed of a conductive material, e.g., metal, is formed on the gate insulating layer **324** to correspond to a center of the semiconductor layer **322**.

(264) An interlayer insulating layer **332**, which is formed of an insulating material, is formed on the gate electrode **330**. The interlayer insulating layer **332** can be formed of an inorganic insulating material, e.g., silicon oxide or silicon nitride, or an organic insulating material, e.g., benzocyclobutene or photo-acryl.

(265) The interlayer insulating layer **332** includes first and second contact holes **334** and **336** exposing both sides of the semiconductor layer **322**. The first and second contact holes **334** and **336** are positioned at both sides of the gate electrode **330** to be spaced apart from the gate electrode **330**.

(266) A source electrode **340** and a drain electrode **342**, which are formed of a conductive material, e.g., metal, are formed on the interlayer insulating layer **332**.

(267) The source electrode **340** and the drain electrode **342** are spaced apart from each other with respect to the gate electrode **330** and respectively contact both sides of the semiconductor layer **322** through the first and second contact holes **334** and **336**.

(268) The semiconductor layer **322**, the gate electrode **330**, the source electrode **340** and the drain electrode **342** constitute the TFT Tr. The TFT Tr serves as a driving element. Namely, the TFT Tr can correspond to the driving TFT Td (of FIG. 1).

(269) The gate line and the data line cross each other to define the pixel region, and the switching TFT is formed to be connected to the gate and data lines. The switching TFT is connected to the TFT Tr as the driving element.

(270) In addition, the power line, which can be formed to be parallel to and spaced apart from one of the gate and data lines, and the storage capacitor for maintaining the voltage of the gate electrode of the TFT Tr in one frame can be further formed.

(271) A planarization layer **350**, which includes a drain contact hole **352** exposing the drain electrode **342** of the TFT Tr, is formed to cover the TFT Tr.

(272) A first electrode **360**, which is connected to the drain electrode **342** of the TFT Tr through the drain contact hole **352**, is separately formed in each pixel region and on a planarization layer **350**. The first electrode **360** can be an anode and can include a transparent conductive layer being formed of a conductive material having a relatively high work function, e.g., a transparent conductive oxide (TCO). The first electrode **360** can further include a reflection electrode or a reflection layer. For example, the reflection electrode or the reflection layer can be formed of silver (Ag) or aluminum-palladium-copper (APC) alloy. In the top-emission organic light emitting display device **30**), the first electrode **360** can have a triple-layered structure of ITO/Ag/ITO or ITO/APC/ITO.

(273) A bank layer **366** covering an edge of the first electrode **360** is formed on the planarization layer **350**. The bank layer **366** is positioned at a boundary of the red, green and blue pixel regions RP, GP and BP and exposes a center of the first electrode **360** in the red, green and blue pixel regions RP, GP and BP. Since the OLED D emits the white light in the red, green and blue pixel regions RP, GP and BP, the organic emitting layer **362** can be formed as a common layer in the red, green and blue pixel regions RP, GP and BP without separation in the red, green and blue pixel regions RP, GP and BP. The bank layer **366** can be formed to prevent the current leakage at an edge of the first electrode **360** and can be omitted.

(274) An organic emitting layer **362** is formed on the first electrode **360**.

(275) Referring to FIG. 5, the organic emitting layer **362** includes a first emitting part **430** including a green EML **410**, a second emitting part **440** including a first blue EML **450** and a third emitting part **460** including a second blue EML **470**. In addition, the organic emitting layer **362** can further include a first charge generation layer (CGL) **480** between the first and second emitting parts **430** and **440** and a second CGL **490** between the first and third emitting parts **430** and **460**. Moreover, the first emitting part **430** can further include a red EML **420**.

(276) The second emitting part **440** is positioned between the first electrode **360** and the first emitting part **430**, and the third emitting part **460** is positioned between the first emitting part **430** and the second electrode **364**. In addition, the second emitting part **440** is positioned between the first electrode **360** and the first CGL **480**, and the third emitting part **460** is positioned between the second CGL **490** and the second electrode **364**. Namely, the second emitting part **440**, the first CGL **480**, the first emitting part **430**, the second CGL **490** and the third emitting part **460** are sequentially stacked on the first electrode **360**.

(277) In the first emitting part **430**, the red EML **420** can be disposed under the green EML **410**. In addition, the first emitting part **430** can further include at least one of a first HTL **432** and a first ETL **434**.

(278) For example, in the first emitting part **430**, the red EML **420** can be positioned between the first HTL **432** and the green EML **410**, and the green EML **410** can be positioned between the red EML **420** and the first ETL **434**.

(279) The second emitting part **440** can further include at least one of a second HTL **444** under the first blue EML **450** and a second ETL **448** on the first blue EML **450**. In addition, the second emitting part **440** can further include an HIL **442** between the first electrode **360** and the second HTL **444**. Moreover, the second emitting part **440** can further include a first EBL **446** between the second HTL **444** and the first blue EML **450**.

(280) The second emitting part **440** can further include a first HBL between the second ETL **448** and the first blue EML **450**.

(281) The third emitting part **460** can further include at least one of a third HTL **462** under the second blue EML **470** and a third ETL **466** on the second blue EML **470**. In addition, the third emitting part **460** can further include an EIL **468** between the second electrode **364** and the third ETL **466**. Moreover, the third emitting part **460** can further include a second EBL **464** between the third HTL **462** and the second blue EML **470**.

(282) The third emitting part **460** can further include a second HBL between the third ETL **466** and the second blue EML **470**.

(283) As described above, the green EML **410** includes the first host **412** being the first compound and the second host **414** being the second compound. In addition, the green EML **410** can further include the green dopant **416**, e.g., the emitter. In the green EML **410**, a weight % of each of the first and second hosts **412** and **414** can be greater than that of the green dopant **416**. For example, the green dopant can be one of a green phosphorescent compound, a green fluorescent compound and a green delayed fluorescent compound.

(284) In the green EML **410**, the first host **412** is represented by Formula 1-1, and the second host **414** is represented by Formula 2-1. In this instance, at least one of the first host **412** and the second host **414** is deuterated. In addition, the green dopant **416** can be represented by Formula 5.

(285) When the green EML **410** includes the first host **412**, the second host **414** and the green dopant **416**, a weight ratio of the first host **412** to the second host **414** can be 1:9 to 9:1, preferably 2:8 to 8:2, and more preferably 3:7 to 7:3. For example, the weight % of the first host **412** can be smaller than that of the second host **414**. The weight ratio of the first host **412** to the second host **414** can be 2:8 to 4:6, preferably 3:7. In addition, in the green EML **410**, the green dopant **416** can have a weight % of 3 weight % to 30 weight %, preferably 5 weight % to 15 weight %.

(286) The red EML **420** can include a red host and a red dopant.

(287) For example, the red host can be a spirofluorene-based organic compound, e.g., a spirofluorene derivative, in Formula 7-1. Alternatively, the red host can be a quinazoline-carbazole-based organic compound, e.g., a quinazoline-carbazole derivative, in Formula 18.

(288) ##STR00072##

(289) In Formula 18, R.sub.121 is selected from the group consisting of deuterium, C1 to C20 alkyl group and C6 to C30 aryl group, and R.sub.122 is C6 to C30 aryl group. Each of R.sub.123 and R.sub.124 is selected from the group consisting of deuterium and C10 to C30 heteroaryl group, or adjacent two R.sub.123 or adjacent two R.sub.124 are connected to each other to form a C6 to C10 aromatic ring. At least one of R.sub.123 and R.sub.124 is C10 to C30 heteroaryl group. Each of o, p and q, which are a number of substituents, is independently an integer of 0 to 4.

(290) For example, the aryl group and the heteroaryl group can be unsubstituted or substituted with C6 to C20 aryl.

(291) The red host in Formula 18 can be one of the compounds in Formula 19.

(292) ##STR00073## ##STR00074## ##STR00075## ##STR00076## ##STR00077##

(293) The red host in the red EML **420** can include the compound in formula 7-1 as a p-type red host and the compound in Formula 18 as an n-type red host. In this instance, the p-type red host and the n-type red host can have a weight ratio of 1:9 to 9:1, preferably 2:8 to 8:2, and more preferably 3:7 to 7:3. For example, the weight % of the p-type red host can be smaller than that of the n-type red host. A weight ratio of the p-type red host to the n-type red host can be 1:9 to 4:6, preferably 3:7.

(294) The red dopant can include at least one of a red phosphorescent compound, a red fluorescent compound and a red delayed fluorescent compound. For example, the red dopant can be represented by Formula 20.

(295) ##STR00078##

(296) In Formula 20, R.sub.131 is selected from the group consisting of deuterium, halogen atom.

C1 to C6 alkyl group, C3 to C6 cycloalkyl group, C6 to C10 aryl group and C3 to C10 heteroaryl group, and r is an integer of 0 to 4. Each of R.sub.132 to R.sub.135 is independently selected from the group consisting of hydrogen, deuterium, halogen atom, C1 to C6 alkyl group, C3 to C6 cycloalkyl group, C6 to C10 aryl group and a C3 to C10 heteroaryl group, and at least adjacent two of R.sub.132 to R.sub.135 are connected to form a C6 to C10 aromatic ring (e.g., a fused ring). Each of R.sub.36 to R.sub.138 is independently selected from the group consisting of hydrogen, deuterium and C1 to C6 alkyl group.

(297) The red dopant can be one of the compounds in Formula 21.

(298) ##STR00079## ##STR00080##

(299) In the red EML **420**, the red dopant can be doped with a weight % of 1 weight % to 10 weight %, preferably 1 weight % to 5 weight %.

(300) For example, in the first emitting part **430**, a thickness of the green EML **410** can be greater than that of the red EML **420**. In addition, a weight % of the green dopant **416** in the green EML **410** can be greater than that of the red dopant in the red EML **420**.

(301) The first blue EML **450** in the second emitting part **440** includes a first blue host and a first blue dopant, and the second blue EML **470** in the third emitting part **460** includes a second blue host and a second blue dopant. Each of the first and second blue hosts can be an anthracene derivative, and each of the first and second blue dopants can be a boron derivative.

(302) For example, each of the first and second blue hosts can be represented by Formula 22-1.

(303) ##STR00081##

(304) In Formula 22-1, each of Ar1 and Ar2 is independently C6 to C20 aryl group, and L is C6 to C20 arylene group.

(305) For example, in Formula 22-1, each of Ar1 and Ar2 can be selected from the group consisting of phenyl, naphthyl and anthracenyl, and L can be selected from the group consisting of phenylene and naphthylene. Ar1 can be 1-naphthyl, Ar2 can be 2-naphthyl, and L can be phenylene.

(306) In this instance, a part or all of hydrogens can be substituted by deuterium. Namely, the anthracene derivative can be partially or wholly deuterated. The first blue host included in the first blue EML **450** being closer to the first electrode **360** as the anode is an anthracene derivative having a first deuteration ratio, and the second blue host included in the second blue EML **470** being closer to the second electrode **364** as the cathode is an anthracene derivative having a second deuteration ratio. For example, the second deuteration ratio can be smaller than the first deuteration ratio.

(307) Namely, in the OLED D, the first blue EML **450** in the second emitting part **440** includes the first blue host being the anthracene derivative, which has a first deuteration ratio, and the second blue EML **470** in the third emitting part **460** includes the second blue host being the anthracene derivative, which has a second deuteration ratio being smaller than the first deuteration ratio.

(308) The first blue host in the first blue EML **450** can be represented by Formula 22-2, and the second blue host in the second blue EML **470** can be represented by Formula 22-3.

(309) ##STR00082##

(310) In Formulas 22-2 and 22-3, each of a1 and a2 is independently an integer of 0 to 8, and each of b1, b2, c1, c2, d1 and d2 is independently an integer of 0 to 20. A summation of a1, b1, c1 and d1 is greater than a summation of a2, b2, c2 and d2. Here, D is deuterium, and each of a1, a2, b1, b2, c1, c2, d1 and d2 is a number of deuterium.

(311) Namely, the first blue host in the first blue EML **450** and the second blue host in the second blue EML **470** can be an anthracene derivative having the same chemical structure (or chemical formula) and have a difference in a deuteration ratio. In other words, the first blue host in the first blue EML **450** has a first deuteration ratio, and the second blue host in the second blue EML **470** has a second deuteration ratio being smaller than the first deuteration ratio.

(312) The first blue host in the first blue EML **450** can be represented by Formula 22-4, and the second blue host in the second blue EML **470** can be represented by Formula 22-5.

(313) ##STR00083##

(314) In Formulas 22-4 and 22-5, each of a1 and a2 is independently an integer of 0 to 8, each of b1, b2, c1 and c2 is independently an integer of 0 to 7, and each of d1 and d2 is independently an integer of 0 to 4. A summation of a1, b1, c1 and d1 is greater than a summation of a2, b2, c2 and d2.

(315) For example, in Formula 22-4, a1 is 8, b1 is 7, c1 is 7, and d1 is 4, thus the first blue host in the first blue EML **450** can be a compound in Formula 23-1. Namely, the first blue host in the first blue EML **450** can be an anthracene derivative, in which all hydrogens are deuterated (e.g., a wholly-deuterated anthracene derivative).

(316) ##STR00084##

(317) For example, in Formula 22-5, at least one of a2, b2, c2 and d2 is 0, thus the second blue host in the second blue EML **470** can be one of compounds in Formula 23-2. Namely, the second blue host in the second blue EML **470** can be an anthracene derivative, in which no hydrogen is deuterated (e.g., a non-deuterated anthracene derivative) or a part of hydrogens are deuterated (e.g., a partially-deuterated anthracene derivative).

(318) ##STR00085## ##STR00086##

(319) Namely, the first blue host in the first blue EML **450** being closer to the first electrode **360** as the anode can have a first deuteration ratio, e.g., 100%, and the second blue host in the second blue EML **470** being closer to the second electrode **364** as the cathode can have a second deuteration ratio, e.g., 0%, about 30%, about 52%, or about 70%, being smaller than the first deuteration ratio.

(320) Each of the first blue dopant in the first blue EML **450** and the second blue dopant in the second blue EML **470** can be a boron derivative represented by Formula 24.

(321) ##STR00087##

(322) In Formula 24, each of R.sub.11 to R.sub.14, each of R.sub.21 to R.sub.24, each of R.sub.31 to R.sub.35 and each of R.sub.41 to R.sub.45 is selected from the group of hydrogen, deuterium (D), C1 to C10 alkyl group, C6 to C30 aryl group unsubstituted or substituted with C1 to C10 alkyl group, C12 to C30 arylamine group and C5 to C30 heteroaryl group, or adjacent two of R.sub.11 to R.sub.14, adjacent two of R.sub.21 to R.sub.24, adjacent two of R.sub.31 to R.sub.35 and adjacent two of R.sub.41 to R.sub.45 are connected (combined) to each other to form a fused ring unsubstituted or substituted with C1 to C10 alkyl group, e.g., an aryl ring or a heteroaryl ring. R.sub.51 is selected from the group consisting of hydrogen, D, C1 to C10 alkyl group and C3 to C15 cycloalkyl group, C6 to C30 aryl group, C5 to C30 heteroaryl group and C6 to C30 arylamine group unsubstituted or substituted with C1 to C10 alkyl group.

(323) Each of R.sub.11 to R.sub.14, each of R.sub.21 to R.sub.24, each of R.sub.31 to R.sub.35 and each of R.sub.41 to R.sub.45 can be same or different.

(324) In the boron derivative being the first and second blue dopant, the benzene ring, which is connected to boron atom and two nitrogen atoms, is substituted with unsubstituted or deuterium-substituted (e.g., D-substituted) C12 to C30 arylamine group or unsubstituted or D-substituted C5 to C30 heteroaryl group such that the emitting property of the OLED D can be further improved. Namely, when R.sub.51 in Formula 24 is unsubstituted or D-substituted C12 to C30 arylamine group or unsubstituted or D-substituted C5 to C30 heteroaryl group, e.g., carbazole, the emitting property of the OLED D can be further improved.

(325) For example, C1 to C10 alkyl group can be one of methyl, ethyl, propyl, butyl, and pentyl (amyl). The substituted or unsubstituted C6 to C30 aryl group can be one of phenyl and naphthyl and can be substituted with D or C1~C10 alkyl. In addition, C12 to C30 arylamine group can be one of diphenylamine group, phenyl-biphenylamine group, phenyl-naphthylamine group, and dinaphthylamine group, and C5 to C30 heteroaryl group can be one of pyridyl, quinolinyl, carbazolyl, dibenzofuranyl, and dibenzothiophenyl. In this instance, arylamine group, aryl group, alkyl group, and heteroaryl group can be substituted with D.

(326) Each of R.sub.11 to R.sub.14, each of R.sub.21 to R.sub.24, each of R.sub.31 to R.sub.35 and

each of R.sub.41 to R.sub.45 can be independently selected from the group consisting of H, D, methyl, ethyl, propyl, butyl, and pentyl (amyl). R.sub.51 can be selected from the group consisting of unsubstituted or D-substituted diphenylamine group, unsubstituted or D-substituted phenyl-biphenylamine group, unsubstituted or D-substituted phenyl-naphthylamine group, unsubstituted or D-substituted biphenyl-naphthylamine group, and unsubstituted or D-substituted carbazoyl.

(327) In one embodiment, one of R.sub.11 to R.sub.14, one of R-n to R.sub.24, one of R.sub.31 to R.sub.35 and one of R.sub.41 to R.sub.45 can be tert-butyl or tert-pentyl (or tert-amyl), and the rest of R.sub.11 to R.sub.14, the rest of R.sub.1 to R.sub.24, the rest of R to R.sub.35 and the rest of R.sub.41 to R.sub.45 can be hydrogen or deuterium, and R.sub.51 can be D-substituted diphenylamine group. When the compound is used as the first and second blue dopants, the emitting efficiency and the color sense of the OLED are improved.

(328) The first and second blue dopants can be same or different and can be independently one of the compounds in Formula 25.

(329) ##STR00088## ##STR00089## ##STR00090## ##STR00091## ##STR00092## ##STR00093##

(330) The first blue dopant can have a weight % of 0.1 weight % to 10 weight %, e.g., 1 weight % to 5 weight %, in the first blue EML **450**, and the second blue dopant can have a weight % of 0.1 weight % to 10 weight %. e.g., 1 weight % to 5 weight %, in the second blue EML **470**. For example, the weight % of the first blue dopant in the first blue EML **450** can be equal to or greater than that of the second blue dopant in the second blue EML **470**.

(331) Each of the first and second blue EMLs **450** and **470** can have a thickness of 10 Å to 1000, e.g., 100 to 500 Å, but it is not limited thereto. For example, the thickness of the first blue EML **450** can be equal to or smaller than that of the second blue EML **470**.

(332) For example, the thickness of the first blue EML **450** can be smaller than that of the second blue EML **470**, and the weight % of the first blue dopant in the first blue EML **450** can be greater than that of the second blue dopant in the second blue EML **470**.

(333) The HIL **442** in the second emitting part **440** includes the compound in Formula 7-1, e.g., a hole injection material. In addition, the HIL **442** can further include one of the compounds in Formula 9 as a p-type dopant.

(334) The first HTL **432** in the first emitting part **430**, the second HTL **444** in the second emitting part **440** and the third HTL **462** in the third emitting part **460** can include the compound in Formula 7-1, e.g., a hole transporting material.

(335) For example, a thickness of the third HTL **462** can be equal to or smaller than that of the second HTL **444** and can be greater than the first HTL **432**. The first HTL **432** can have a thickness of about 10 to 150 Å, the second HTL **444** can have a thickness of about 50) to 1000 Å, and the third HTL **462** can have a thickness of about 500 to 900 Å.

(336) In the HIL **442**, a weight ratio of the first hole injection material to the second hole injection material can be 8:2 to 5:5, and the HIL **442** can have a thickness of about 10 to 100 Å.

(337) Each of the first to third ETL **434**, **448** and **466** can include at least one of the benzimidazole-based organic compound in Formula 10 and the azine-based organic compound in Formula 12.

(338) For example, each of the first and third ETL **434** and **466** can include the electron transporting material in Formula 10, and the second ETL **448** can include the electron transporting material in Formula 12. The third ETL **466** can further include the electron transporting material in Formula 12. Namely, the first ETL **434** can include a single material of the electron transporting material in Formula 10, the second ETL **448** can include a single material of the electron transporting material in Formula 12, while the third ETL **466** can include two materials of the electron transporting materials in Formulas 10 and 12. In the third ETL **466**, the electron transporting material in Formula 10 and the electron transporting material in Formula 12 can have the same weight %.

(339) The EIL **468** can include the electron injection material being the compound in Formula 14.

In addition, the EIL **468** can further include a dopant being one of alkali metal, e.g., Li, Na, K or Cs, and alkali earth metal, e.g., Mg, Sr, Ba or Ra.

(340) Each of the first EBL **446** in the second emitting part **440** and the second EBL **464** in the third emitting part **460** can include the electron blocking material being the compound in formula 16.

(341) The first CGL **480** is positioned between the first emitting part **430** and the second emitting part **440**, and the second CGL **490** is positioned between the first emitting part **430** and the third emitting part **460**. Namely, the first and second emitting parts **430** and **440** are connected through the first CGL **480**, and the first and third emitting parts **430** and **460** are connected through the second CGL **490**. The first CGL **480** can be a P-N junction CGL of an N-type CGL **482** and a P-type CGL **484**, and the second CGL **490** can be a P-N junction CGL of an N-type CGL **492** and a P-type CGL **494**.

(342) In the first CGL **480**, the N-type CGL **482** is positioned between the first HTL **432** and the second ETL **448**, and the P-type CGL **484** is positioned between the N-type CGL **482** and the first HTL **432**.

(343) In the second CGL **490**, the N-type CGL **492** is positioned between the first ETL **434** and the third HTL **462**, and the P-type CGL **494** is positioned between the N-type CGL **492** and the third HTL **462**.

(344) Each of the N-type CGL **482** in the first CGL **480** and the N-type CGL **492** in the second CGL **490** can include a phenanthroline-based compound of Formula 14 as an N-type charge generation material.

(345) Each of the N-type CGL **482** in the first CGL **480** and the N-type CGL **492** in the second CGL **490** can further include a dopant being at least one of alkali metal, e.g., Li, Na, K or Cs, and alkali earth metal, e.g., Mg, Sr, Ba or Ra. In this instance, the electron generation property and/or the electron injection property of the N-type CGLs **482** and **492** can be improved. In each of the N-type CGLs **482** and **492**, the dopant can have a weight % of 0.1 weight % to 10 weight %. In addition, each of the N-type CGLs **482** and **492** can have a thickness of 30 to 500 Å, preferably 50 to 300 Å. For example, the weight % of the dopant in the N-type CGL **482** in the first CGL **480** can be greater than that of the dopant in the N-type CGL **492** in the second CGL **490**, and the thickness of the N-type CGL **482** in the first CGL **480** can be smaller than that of the N-type CGL **492** in the second CGL **490**.

(346) Each of the P-type CGL **484** in the first CGL **480** and the P-type CGL **494** in the second CGL **490** can include the compound in Formula 7-1 as a p-type charge generation material.

(347) In addition, each of the P-type CGL **484** in the first CGL **480** and the P-type CGL **494** in the second CGL **490** can include the compound in Formula 9 as a dopant.

(348) In each of the P-type CGLs **484** and **494**, the dopant can have a weight % of 1 weight % to 40 weight %, preferably 3 weight % to 30 weight %. In addition, each of the P-type CGLs **484** and **494** can have a thickness of 30 to 500 Å, preferably 50 to 200 Å.

(349) For example, the weight % of the dopant in the P-type CGL **484** in the first CGL **480** can be equal to that of the dopant in the P-type CGL **494** in the second CGL **490**, and the thickness of the P-type CGL **484** in the first CGL **480** can be smaller than that of the P-type CGL **494** in the second CGL **490**.

(350) As described above, the OLED D of the present disclosure includes the first emitting part **430**, which includes the green EML **410** and the red EML **420**, the second emitting part **440**, which includes the first blue EML **450**, and the third emitting part **460**, which includes the second blue EML **470**, so that the white light is provided from the OLED D.

(351) The green EML **410** includes the first host **412** and the second host **414**, and at least one of the first and second hosts **412** and **414** is deuterated. Accordingly, the emitting efficiency and the lifespan of the OLED D and the organic light emitting display device **300** are increased.

(352) In addition, when only the fused-hetero ring moiety in the first host **412** is deuterated and/or

only the biscarbazole moiety in the second host **414** is deuterated, the lifespan of the OLED D and the organic light emitting display device **300** is further improved.

(353) Moreover, the first blue host of the first blue EML **450** is an anthracene derivative having a first deuteration ratio, and the second blue host of the second blue EML **470** is an anthracene derivative having a second deuteration ratio, which is smaller than the first deuteration ratio. Accordingly, the emitting efficiency and the lifespan of the OLED D and the organic light emitting display device **300** are further increased.

(354) Referring to FIG. 6, the organic emitting layer **362** includes a first emitting part **530**, which includes a green EML **510**, a red EML **520** and a yellow-green EML **525**, a second emitting part **540** including a first blue EML **550**, and a third emitting part **560** including a second blue EML **570**. In addition, the organic emitting layer **362** can further include a first CGL **580** between the first and second emitting parts **530** and **540** and a second CGL **590** between the first and third emitting parts **530** and **560**.

(355) The second emitting part **540** is positioned between the first electrode **360** and the first emitting part **530**, and the third emitting part **560** is positioned between the first emitting part **530** and the second electrode **364**. In addition, the second emitting part **540** is positioned between the first electrode **360** and the first CGL **580**, and the third emitting part **560** is positioned between the second CGL **590** and the second electrode **364**. Namely, the second emitting part **540**, the first CGL **580**, the first emitting part **530**, the second CGL **590** and the third emitting part **560** are sequentially stacked on the first electrode **360**.

(356) In the first emitting part **530**, the red EML **520** is disposed under the yellow-green EML **525**, and the green EML **510** is disposed over the yellow-green EML **525**. Namely, the EML having a double-layered structure is included in the first emitting part **430** of the OLED in FIG. 5, while the EML having a triple-layered structure is included in the first emitting part **530** of the OLED in FIG. 6.

(357) In addition, the first emitting part **530** can further include at least one of a first HTL **532** and a first ETL **534**.

(358) The second emitting part **540** can further include at least one of a second HTL **544** under the first blue EML **550** and a second ETL **548** on the first blue EML **550**. In addition, the second emitting part **540** can further include an HIL **542** between the first electrode **360** and the second HTL **544**. Moreover, the second emitting part **540** can further include a first EBL **546** between the second HTL **544** and the first blue EML **550**.

(359) The second emitting part **540** can further include a first HBL between the second ETL **548** and the first blue EML **550**.

(360) The third emitting part **560** can further include at least one of a third HTL **562** under the second blue EML **570** and a third ETL **566** on the second blue EML **570**. In addition, the third emitting part **560** can further include an EIL **568** between the second electrode **364** and the third ETL **566**. Moreover, the third emitting part **560** can further include a second EBL **564** between the third HTL **562** and the second blue EML **570**.

(361) The third emitting part **560** can further include a second HBL between the third ETL **566** and the second blue EML **570**.

(362) As described above, the green EML **510** includes the first host **512** being the first compound and the second host **514** being the second compound. In addition, the green EML **510** can further include the green dopant **516**, e.g., the emitter. In the green EML **510**, a weight % of each of the first and second hosts **512** and **514** can be greater than that of the green dopant **516**. For example, the green dopant can be one of a green phosphorescent compound, a green fluorescent compound and a green delayed fluorescent compound.

(363) In the green EML **510**, the first host **512** is represented by Formula 1-1, and the second host **514** is represented by Formula 2-1. In this instance, at least one of the first host **512** and the second host **514** is deuterated. In addition, the green dopant **516** can be represented by Formula 5.

(364) When the green EML **510** includes the first host **512**, the second host **514** and the green dopant **516**, a weight ratio of the first host **512** to the second host **514** can be 1:9 to 9:1, preferably 2:8 to 8:2, and more preferably 3:7 to 7:3. For example, the weight % of the first host **512** can be smaller than that of the second host **514**. The weight ratio of the first host **512** to the second host **514** can be 2:8 to 4:6, preferably 3:7. In addition, in the green EML **510**, the green dopant **516** can have a weight % of 3 weight % to 30 weight %, preferably 5 weight % to 15 weight %.

(365) The red EML **520** can include a red host and a red dopant.

(366) For example, the red host can be a spirofluorene-based organic compound, e.g., a spirofluorene derivative, in Formula 7-1 and can be one of the compounds in Formula 8. Alternatively, the red host can be a quinazoline-carbazole-based organic compound, e.g., a quinazoline-carbazole derivative, in Formula 18 and can be one of the compounds in Formula 19. The red EML **520** can include both the compound in Formula 7-1 as a first red host and the compound in Formula 18 as a second red host.

(367) The red dopant can include at least one of a red phosphorescent compound, a red fluorescent compound and a red delayed fluorescent compound. For example, the red dopant can be represented by Formula 20 and can be one of the compounds in Formula 21.

(368) The yellow-green EML **525** can include a first yellow-green host and a yellow-green dopant. In addition, the yellow-green EML **525** can further include a second yellow-green host.

(369) The first yellow-green host can be a P-type host and can be represented by Formula 27.

(370) ##STR00094##

(371) In Formula 27, each of R.sub.1 to R.sub.7 and R.sub.11 to R.sub.17 is independently hydrogen or deuterium. Each of R.sub.21 to R.sub.25 and R.sub.31 to R.sub.35 is independently selected from the group consisting of hydrogen, deuterium, C1 to C10 alkyl group and C6 to C30 aryl group unsubstituted or substituted with deuterium, or adjacent two of R.sub.21 to R.sub.25 and/or adjacent two of R.sub.31 to R.sub.35 are combined (or linked) to each other to form a fused ring. For example, the fused ring can be an aromatic ring.

(372) The first yellow-green host in Formula 27 can be one of the compounds in Formula 28.

(373) ##STR00095## ##STR00096## ##STR00097## ##STR00098## ##STR00099##
##STR00100##

(374) The second yellow-green host can be an N-type host and can be represented by Formula 29.

(375) ##STR00101##

(376) In Formula 29, each of Ar and Ar₂ is independently C6 to C30 aryl group, each of R.sub.1 and R.sub.2 is independently selected from the group consisting of hydrogen, C1 to C10 alkyl group and C6 to C30 aryl group, and L is C6 to C30 arylene group.

(377) For example, each of Ar.sub.1 and Ar.sub.2 can be independently phenyl or naphthyl, each of R.sub.1 and R.sub.2 can be C1 to C10 alkyl, and L can be phenylene or naphthylene.

(378) The second yellow-green host in Formula 29 can be one of the compounds in Formula 30.

(379) ##STR00102## ##STR00103## ##STR00104## ##STR00105## ##STR00106##
##STR00107## ##STR00108## ##STR00109##

(380) The yellow-green dopant can be represented by Formula 31.

(381) ##STR00110##

(382) In Formula 31, R.sub.1 is C6 to C30 aryl group, and n is an integer of 0 to 3.

(383) The yellow-green dopant can be the compound in Formula 32.

(384) ##STR00111##

(385) In the yellow-green EML **525**, the yellow-green dopant can have a weight % of 3 weight % to 30 weight %. The yellow-green EML **525** can have a thickness of 50 to 400 Å.

(386) When the yellow-green EML **525** includes the first yellow-green host and the second yellow-green host, a weight ratio of the first yellow-green host to the second yellow-green host can be 1:9 to 9:1, preferably 2:8 to 8:2, and more preferably 3:7 to 7:3. For example, the yellow-green EML **525** can have a thickness of 300 Å, the first yellow-green host and the second yellow-green host

can have the same weight %, and the yellow-green dopant can be doped by 15 weight %.

(387) The first blue EML **550** in the second emitting part **540** includes a first blue host and a first blue dopant, and the second blue EML **570** in the third emitting part **560** includes a second blue host and a second blue dopant. Each of the first and second blue hosts can be an anthracene derivative, and each of the first and second blue dopants can be a boron derivative.

(388) For example, the first blue host in the first blue EML **550** can be represented by Formula 22-2 or Formula 22-4, and the second blue host in the second blue EML **570** can be represented by Formula 22-3 or Formula 22-5.

(389) Namely, the first blue host in the first blue EML **550** and the second blue host in the second blue EML **570** can be the anthracene derivative having the same structure and can have a difference in a deuteration ratio. In other words, the first blue host in the first blue EML **550** can have a first deuteration ratio, and the second blue host in the second blue EML **570** can have a second deuteration ratio being smaller than the first deuteration ratio.

(390) Each of the first blue dopant in the first blue EML **550** and the second blue dopant in the second blue EML **570** can be represented by Formula 25.

(391) The first blue dopant can have a weight % of 0.1 to 10, e.g., 1 to 5, in the first blue EML **550**, and the second blue dopant can have a weight % of 0.1 to 10, e.g., 1 to 5, in the second blue EML **570**. For example, the weight % of the first blue dopant in the first blue EML **550** can be equal to or greater than that of the second blue dopant in the second blue EML **570**.

(392) Each of the first and second blue EMLs **550** and **570** can have a thickness of 100 Å to 1000 Å, e.g., 100 Å to 500 Å, but it is not limited thereto. For example, the thickness of the first blue EML **550** can be equal to or smaller than that of the second blue EML **570**.

(393) For example, the thickness of the first blue EML **550** can be smaller than that of the second blue EML **570**, and the weight % of the first blue dopant in the first blue EML **550** can be greater than that of the second blue dopant in the second blue EML **570**.

(394) The HIL **542** in the second emitting part **540** can include the hole injection material in Formula 7-1. In addition, the HIL **542** can further include the compound in Formula 9 as a p-type dopant.

(395) Each of the first HTL **532** in the first emitting part **530**, the second HTL **544** in the second emitting part **540** and the third HTL **562** in the third emitting part **560** can include the compound in Formula 7-1 as a hole transporting material.

(396) For example, a thickness of the third HTL **562** can be equal to or smaller than that of the second HTL **544** and can be greater than the first HTL **532**. The first HTL **532** can have a thickness of about 10 to 150 Å, the second HTL **544** can have a thickness of about 500 to 1000 Å, and the third HTL **562** can have a thickness of about 500 to 900 Å.

(397) Each of the first to third ETL **534**, **548** and **566** can include at least one of the benzimidazole-based organic compound in Formula 10 and the azine-based organic compound in Formula 12.

(398) For example, each of the first and third ETL **534** and **566** can include the electron transporting material in Formula 10, and the second ETL **548** can include the electron transporting material in Formula 12. The third ETL **566** can further include the electron transporting material in Formula 12. In the third ETL **566**, the electron transporting material in Formula 10 and the electron transporting material in Formula 12 can have the same weight %.

(399) The EIL **568** in the third emitting part **560** can include the compound in Formula 15 as an electron injection material. In addition, the EIL **568** can further include a dopant being at least one of alkali metal, e.g., Li, Na, K or Cs, and alkali earth metal, e.g., Mg, Sr, Ba or Ra.

(400) Each of the first EBL **546** in the second emitting part **540** and the second EBL **564** in the third emitting part **560** can include the electron blocking material in formula 17.

(401) The first CGL **580** is positioned between the first emitting part **530** and the second emitting part **540**, and the second CGL **590** is positioned between the first emitting part **530** and the third emitting part **560**. Namely, the first and second emitting parts **530** and **540** are connected through

the first CGL **580**, and the first and third emitting parts **530** and **560** are connected through the second CGL **590**. The first CGL **580** can be a P-N junction CGL of an N-type CGL **582** and a P-type CGL **584**, and the second CGL **590** can be a P-N junction CGL of an N-type CGL **592** and a P-type CGL **594**.

(402) In the first CGL **580**, the N-type CGL **582** is positioned between the first HTL **532** and the second ETL **548**, and the P-type CGL **584** is positioned between the N-type CGL **582** and the first HTL **532**.

(403) In the second CGL **590**, the N-type CGL **592** is positioned between the first ETL **534** and the third HTL **562**, and the P-type CGL **594** is positioned between the N-type CGL **592** and the third HTL **562**.

(404) Each of the N-type CGL **582** in the first CGL **580** and the N-type CGL **592** in the second CGL **590** can include the phenanthroline-based compound of Formula 14 and can include one of the compounds in Formula 15.

(405) Each of the N-type CGL **582** in the first CGL **580** and the N-type CGL **592** in the second CGL **590** can further include a dopant being one of alkali metal, e.g., Li, Na, K or Cs, and alkali earth metal, e.g., Mg, Sr, Ba or Ra. In this instance, the electron generation property and/or the electron injection property of the N-type CGLs **582** and **592** can be improved. In each of the N-type CGLs **582** and **592**, the dopant can have a weight % of 0.1 weight % to 10 weight %. In addition, each of the N-type CGLs **582** and **592** can have a thickness of 30 to 500 Å, preferably 50 to 300 Å. For example, the weight % of the dopant in the N-type CGL **582** in the first CGL **580** can be greater than that of the dopant in the N-type CGL **592** in the second CGL **590**, and the thickness of the N-type CGL **582** in the first CGL **580** can be smaller than that of the N-type CGL **592** in the second CGL **590**.

(406) Each of the P-type CGL **584** in the first CGL **580** and the P-type CGL **594** in the second CGL **590** can include the compound in Formula 7-1. In addition, each of the P-type CGL **584** in the first CGL **580** and the P-type CGL **594** in the second CGL **590** can further include the compound in Formula 9 as a dopant.

(407) In each of the P-type CGL **584** in the first CGL **580** and the P-type CGL **594** in the second CGL **590**, the dopant can have a weight % of 1 weight % to 40 weight %, preferably 3 weight % to 30 weight %. Each of the P-type CGL **584** in the first CGL **580** and the P-type CGL **594** in the second CGL **590** can have a thickness of 30 to 500 Å, preferably 50 to 200 Å.

(408) For example, the weight % of the dopant in the P-type CGL **584** of the first CGL **580** can be equal to that of the dopant in the P-type CGL **594** of the second CGL **590**, and the thickness of the P-type CGL **584** in the first CGL **580** can be smaller than that of the P-type CGL **594** in the second CGL **590**.

(409) As described above, the OLED D of the present disclosure includes the first emitting part **530**, which includes the green EML **510**, the red EML **520** and the yellow-green EML **525**, the second emitting part **540**, which includes the first blue EML **550**, and the third emitting part **560**, which includes the second blue EML **570**, so that the white light is provided from the OLED D.

(410) The green EML **510** includes the first host **512** and the second host **514**, and at least one of the first and second hosts **512** and **514** is deuterated. Accordingly, the emitting efficiency and the lifespan of the OLED D and the organic light emitting display device **300** are increased.

(411) In addition, when only the fused-hetero ring moiety in the first host **512** is deuterated and/or only the biscarbazole moiety in the second host **514** is deuterated, the lifespan of the OLED D and the organic light emitting display device **300** is further improved.

(412) Moreover, the first blue host of the first blue EML **550** is an anthracene derivative having a first deuteration ratio, and the second blue host of the second blue EML **570** is an anthracene derivative having a second deuteration ratio, which is smaller than the first deuteration ratio. Accordingly, the emitting efficiency and the lifespan of the OLED D and the organic light emitting display device **300** are further increased.

(413) Referring to FIG. 4 again, a second electrode **364** is formed over the first substrate **310** where the organic emitting layer **362** is formed.

(414) In the organic light emitting display device **300**, since the light emitted from the organic emitting layer **362** is incident to the color filter layer **380** through the second electrode **364**, the second electrode **364** has a thin profile for transmitting the light.

(415) The first electrode **360**, the organic emitting layer **362** and the second electrode **364** constitute the OLED D.

(416) The color filter layer **380** is positioned over the OLED D and includes a red color filter **382**, a green color filter **384** and a blue color filter **386** respectively corresponding to the red, green and blue pixel regions RP, GP and BP. The red color filter **382** can include at least one of a red dye and a red pigment, the green color filter **384** can include at least one of a green dye and a green pigment, and the blue color filter **386** can include at least one of a blue dye and a blue pigment.

(417) The color filter layer **380** can be attached to the OLED D by using an adhesive layer. Alternatively, the color filter layer **380** can be formed directly on the OLED D.

(418) An encapsulation film can be formed to prevent penetration of moisture into the OLED D. For example, the encapsulation film can include a first inorganic insulating layer, an organic insulating layer and a second inorganic insulating layer sequentially stacked, but it is not limited thereto. The encapsulation film can be omitted.

(419) A polarization plate for reducing an ambient light reflection can be disposed at an outer side of the second substrate **370**. For example, the polarization plate can be a circular polarization plate.

(420) In the organic light emitting display device **300** of FIG. 4, the first electrode **360** and the second electrode **364** are a reflective electrode and a transparent (semitransparent) electrode, respectively, and the color filter layer **380** is disposed over the OLED D. Alternatively, the first electrode **360** and the second electrode **364** are a transparent (semitransparent) electrode and a reflective electrode, respectively, and the color filter layer **380** can be disposed between the OLED D and the first substrate **310**.

(421) A color conversion layer can be formed between the OLED D and the color filter layer **380**. The color conversion layer can include a red color conversion layer, a green color conversion layer and a blue color conversion layer respectively corresponding to the red, green and blue pixel regions RP, GP and BP. The white light from the OLED D is converted into the red light, the green light and the blue light by the red, green and blue color conversion layer, respectively. For example, the color conversion layer can include a quantum dot. The color purity of the organic light emitting display device **300** can be further improved due to the color conversion layer.

(422) Alternatively, the color conversion layer can be included instead of the color filter layer **380**.

(423) As described above, the white light from the organic light emitting diode D passes through the red color filter **382**, the green color filter **384** and the blue color filter **386** in the red pixel region RP, the green pixel region GP and the blue pixel region BP such that the red light, the green light and the blue light are provided from the red pixel region RP, the green pixel region GP and the blue pixel region BP, respectively.

(424) In FIG. 4, the OLED D emitting the white light is used for a display device. Alternatively, the OLED D can be formed on an entire surface of a substrate without at least one of the driving element and the color filter layer to be used for a lightening device. The display device and the lightening device each including the OLED D of the present disclosure can be referred to as an organic light emitting device.

(425) In the OLED D and the organic light emitting display device **300**, the green EML includes the first host, which includes a fused-hetero ring moiety, and the second host, which includes a bis-carbazole moiety, and at least one of the first and second hosts is deuterated. Accordingly, the emitting efficiency and the lifespan of the OLED D and the organic light emitting display device **300** are increased.

(426) In addition, when only the fused-hetero ring moiety in the first host is deuterated and/or only

the biscarbazole moiety in the second host is deuterated, the lifespan of the OLED D and the organic light emitting display device **300** is further improved.

(427) It will be apparent to those skilled in the art that various modifications and variations can be made in the embodiments of the present disclosure without departing from the spirit or scope of the present disclosure. Thus, it is intended that the modifications and variations cover this disclosure provided they come within the scope of the appended claims and their equivalents.

Claims

1. An organic light emitting diode, comprising: a first electrode; a second electrode facing the first electrode; a first emitting part including a green emitting material layer and positioned between the first and second electrodes, the green emitting material layer including a first host, a second host and a dopant; a second emitting part including a first blue emitting material layer and positioned between the first electrode and the first emitting part; a first charge generation layer including a P-type charge generation material and positioned between the first emitting part and the second emitting part; a third emitting part including a second blue emitting material layer and positioned between the first emitting part and the second electrode; and a second charge generation layer positioned between the first emitting part and the third emitting part, wherein the first host is represented by Formula 1-1: ##STR00112## wherein D denotes a deuterium atom, X is oxygen or sulfur, a1 is an integer of 0 to 10, wherein b1 is an integer of 0 to 4, and each of c1 and d1 is independently an integer of 0 to 5, wherein the second host is represented by Formula 2-1: ##STR00113## wherein a2 is an integer of 0 to 14, and each of b2 and c2 is independently an integer of 0 to 9, and wherein at least one of a1, a2, b1, b2, c1, c2 and d1 is a positive integer.
2. The organic light emitting diode according to claim 1, wherein a1 is an integer of 1 to 10 and each of b1, c1 and d1 is 0.
3. The organic light emitting diode according to claim 2, wherein the first host is one of following compounds host 1-4 and host 2-4, and the second host is one of compounds in Formula 4: ##STR00114## ##STR00115## ##STR00116##
4. The organic light emitting diode according to claim 1, wherein a2 is an integer from 1 to 14, and each of b2 and c2 is 0.
5. The organic light emitting diode according to claim 4, wherein the first host is selected from compounds Host 1-1 to Host 1-5 and Host 2-1 to Host 2-5, and the second host is the following compound host 3-3: ##STR00117## ##STR00118## ##STR00119## ##STR00120##
6. The organic light emitting diode according to claim 1, wherein the first blue emitting material layer includes a first blue host of Formula 22-2, and the second blue emitting material layer includes a second blue host of Formula 22-3: ##STR00121## wherein each of Ar1 and Ar2 is independently C6 to C20 aryl group, and L is C6 to C20 arylene group, wherein each of a1 and a2 is independently an integer of 0 to 8, and each of b1, b2, c1, c2, d1 and d2 is independently an integer of 0 to 20, and wherein a summation of a1, b1, c1 and d1 is greater than a summation of a2, b2, c2 and d2.
7. The organic light emitting diode according to claim 6, wherein the first blue host is represented by Formula 22-4, and the second blue host is represented by Formula 22-5: ##STR00122## wherein each of a1 and a2 is independently an integer of 0 to 8, each of b1, b2, c1 and c2 is independently an integer of 0 to 7, wherein each of d1 and d2 is independently an integer of 0 to 4, and wherein a summation of a1, b1, c1 and d1 is greater than a summation of a2, b2, c2 and d2.
8. The organic light emitting diode according to claim 7, wherein the first blue host is a compound in Formula 23-1: ##STR00123##
9. The organic light emitting diode according to claim 7, wherein the second blue host is one of compounds in Formula 23-2: ##STR00124## ##STR00125##
10. The organic light emitting diode according to claim 6, wherein the first blue emitting material

layer includes a first blue dopant being a boron derivative, and the second blue emitting material layer includes a second blue dopant being a boron derivative.

11. The organic light emitting diode according to claim 10, wherein each of the first and second blue dopants is represented by Formula 24: ##STR00126## wherein each of R.sub.11 to R.sub.14, each of R.sub.21 to R.sub.24, each of R.sub.31 to R.sub.35 and each of R.sub.41 to R.sub.45 is selected from the group of hydrogen, deuterium, C1 to C10 alkyl group, C6 to C30 aryl group unsubstituted or substituted with C1 to C10 alkyl group, C12 to C30 arylamine group and C5 to C30 heteroaryl group, or adjacent two of R.sub.11 to R.sub.14, adjacent two of R.sub.21 to R.sub.24, adjacent two of R.sub.31 to R.sub.35 and adjacent two of R.sub.41 to R.sub.45 are connected to each other to form a fused ring unsubstituted or substituted with C1 to C10 alkyl group, and wherein R.sub.51 is selected from the group consisting of hydrogen, deuterium, C1 to C10 alkyl group and C3 to C30 cycloalkyl group, C6 to C30 aryl group, C5 to C30 heteroaryl group and C6 to C30 arylamine group unsubstituted or substituted with C1 to C10 alkyl group.

12. The organic light emitting diode according to claim 11, wherein each of the first and second blue dopants is independently selected from compounds in Formula 25: ##STR00127## ##STR00128## ##STR00129## ##STR00130## ##STR00131## ##STR00132##

13. The organic light emitting diode according to claim 11, wherein a weight % of the first blue dopant in the first blue emitting material layer is equal to or greater than a weight % of the second blue dopant in the second blue emitting material layer.

14. The organic light emitting diode according to claim 13, wherein a thickness of the first blue emitting material layer is equal to or smaller than a thickness of the second blue emitting material layer.

15. The organic light emitting diode according to claim 1, wherein the first emitting part further includes a red emitting material layer between the green emitting material layer and the first charge generation layer.

16. The organic light emitting diode according to claim 15, wherein the first emitting part further includes a yellow-green emitting material layer between the red and green emitting material layers.

17. An organic light emitting device, comprising: a substrate; and an organic light emitting diode positioned on the substrate and including a first electrode, a second electrode facing the first electrode, a first emitting part including a green emitting material layer and positioned between the first and second electrodes, a second emitting part including a first blue emitting material layer and positioned between the first electrode and the first emitting part, a first charge generation layer including a P-type charge generation material and positioned between the first emitting part and the second emitting part, a third emitting part including a second blue emitting material layer and positioned between the first emitting part and the second electrode, and a second charge generation layer positioned between the first emitting part and the third emitting part, the green emitting material layer including a first host, a second host and a dopant, wherein the first host is represented by Formula 1-1: ##STR00133## wherein X is oxygen or sulfur, a1 is an integer of 0 to 10, wherein b1 is an integer of 0 to 4, and each of c1 and d1 is independently an integer of 0 to 5, wherein the second host is represented by Formula 2-1: ##STR00134## wherein a2 is an integer of 0 to 14, and each of b2 and c2 is independently an integer of 0 to 9, and wherein at least one of a1, a2, b1, b2, c1, c2 and d1 is a positive integer.

18. The organic light emitting device according to claim 17, wherein a1 is an integer from 1 to 10 and each of b1, c1 and d1 is 0.

19. The organic light emitting device according to claim 17, wherein a2 is an integer from 1 to 14, and each of b2 and c2 is 0.
