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(19) **United States**(12) **Patent Application Publication**
LEE et al.(10) **Pub. No.: US 2017/0125732 A1**(43) **Pub. Date: May 4, 2017**(54) **FLEXIBLE ORGANIC LIGHT EMITTING
DISPLAY DEVICE AND METHOD OF
FABRICATING THE SAME****Publication Classification**(51) **Int. Cl.****H01L 51/52** (2006.01)**H01L 51/00** (2006.01)**H01L 51/56** (2006.01)**H01L 27/32** (2006.01)(52) **U.S. Cl.**CPC **H01L 51/5253** (2013.01); **H01L 27/3244**(2013.01); **H01L 51/0097** (2013.01); **H01L****51/56** (2013.01); **H01L 2251/5338** (2013.01);**H01L 2251/301** (2013.01); **H01L 2251/5346**(2013.01); **H01L 2227/323** (2013.01)(71) Applicant: **LG Display Co., Ltd.**, Seoul (KR)(72) Inventors: **Jae-Young LEE**, Paju-si (KR); **Ji-Min KIM**, Seoul (KR); **Gi-Youn KIM**, Goyang-si (KR); **Sang-Hoon OH**, Jeollabuk-do (KR); **Wan-Soo LEE**, Jeonju-si (KR)(21) Appl. No.: **15/288,811**(22) Filed: **Oct. 7, 2016**(30) **Foreign Application Priority Data**

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(57)

ABSTRACT

A flexible organic light emitting display (OLED) device includes an organic emitting diode on a flexible substrate, an encapsulation film covering the organic emitting diode and including a first inorganic layer and an organic layer. The first inorganic layer is formed of a first material, and at least a portion of the first inorganic layer includes a dopant that increases the surface energy of the doped material compared to that of non-doped material.

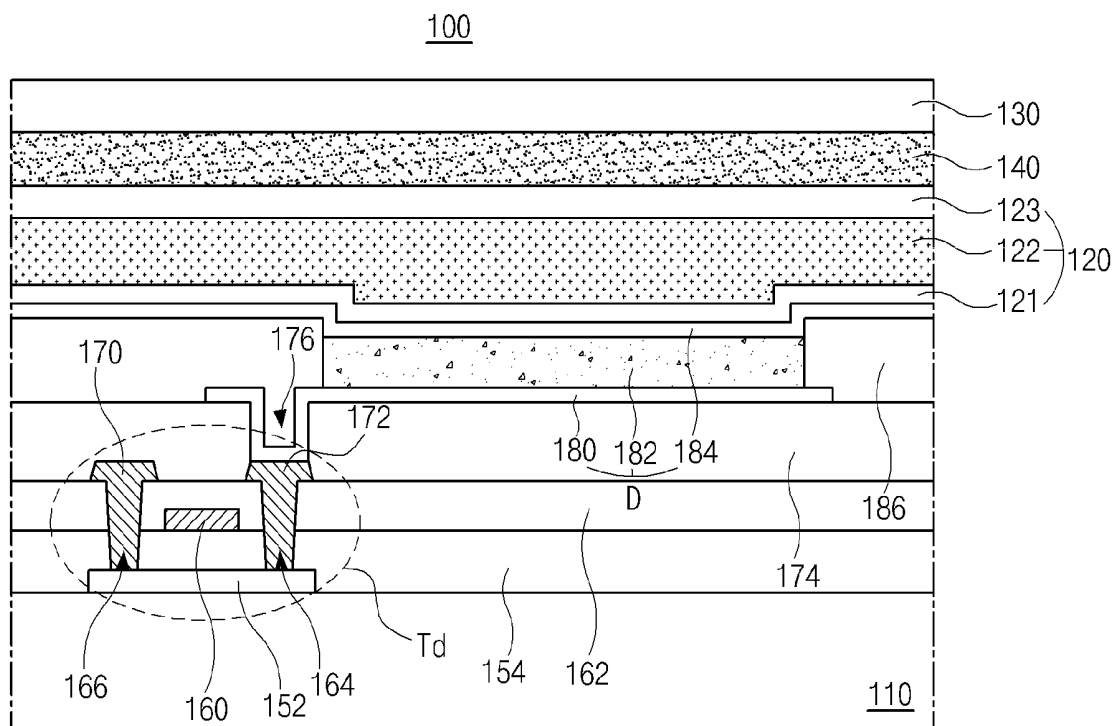


FIG. 1
Related Art

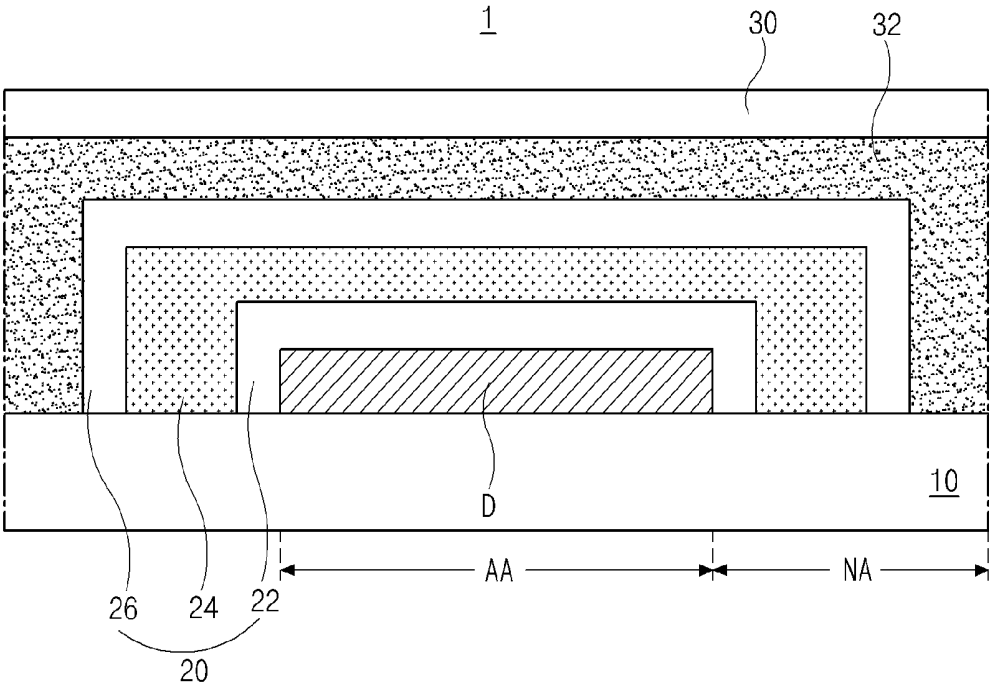


FIG. 2

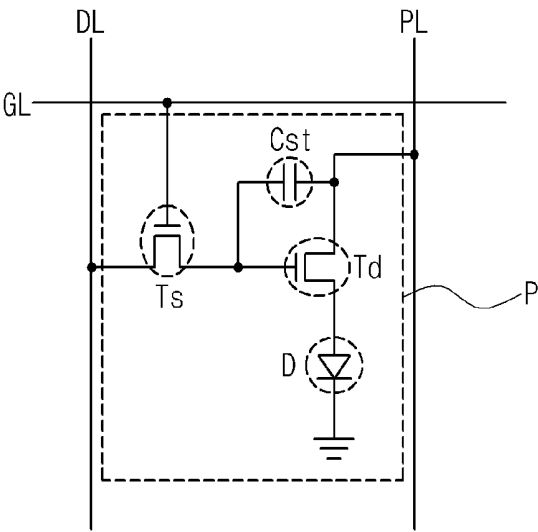


FIG. 3

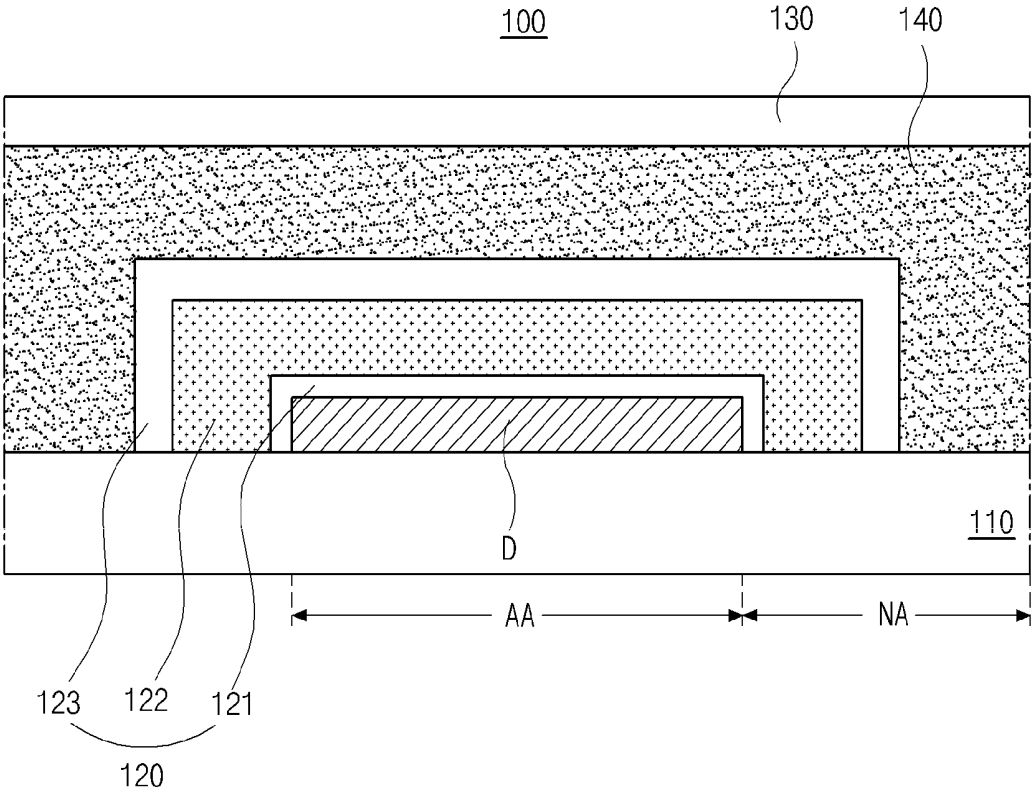


FIG. 4

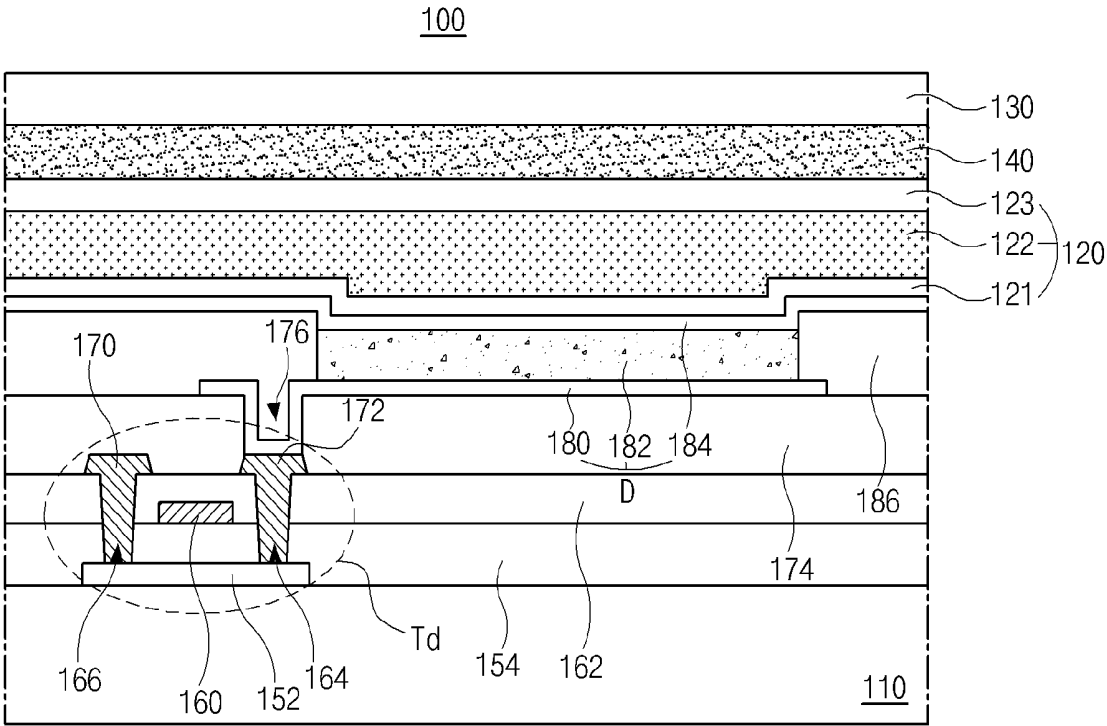


FIG. 5

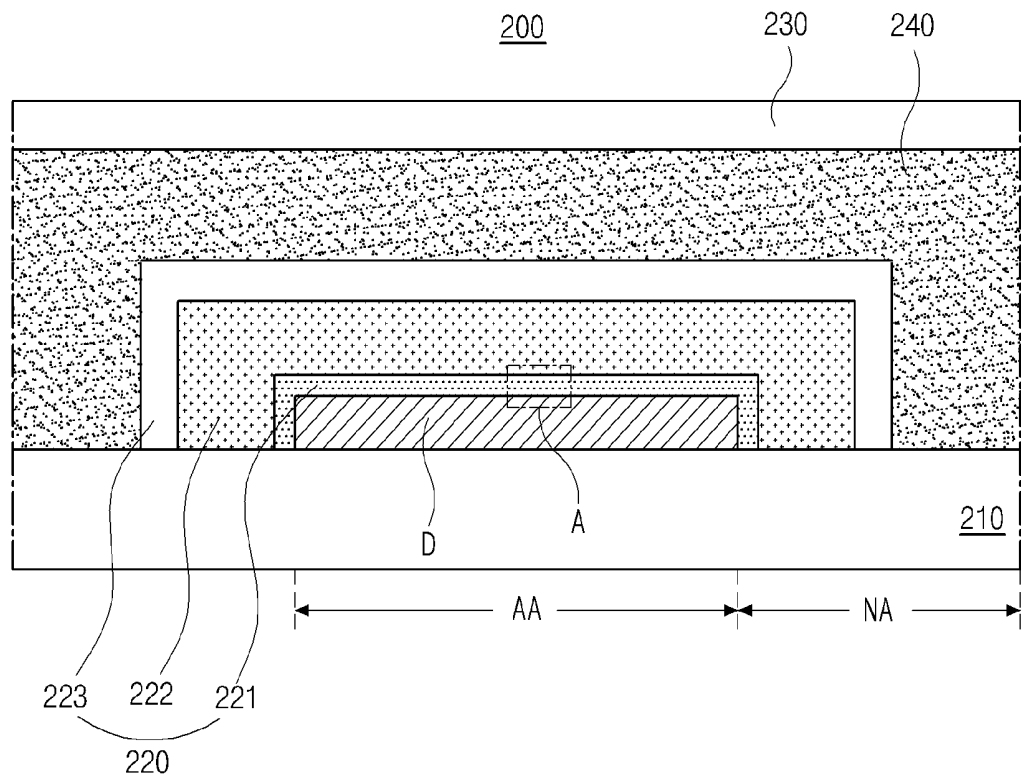


FIG. 6A

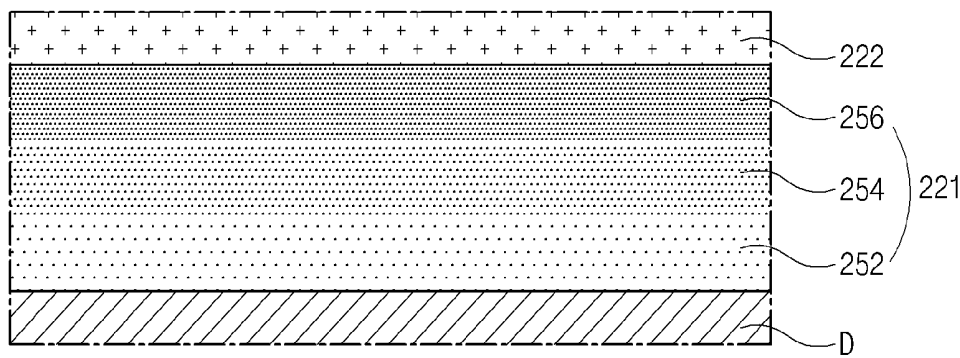


FIG. 6B

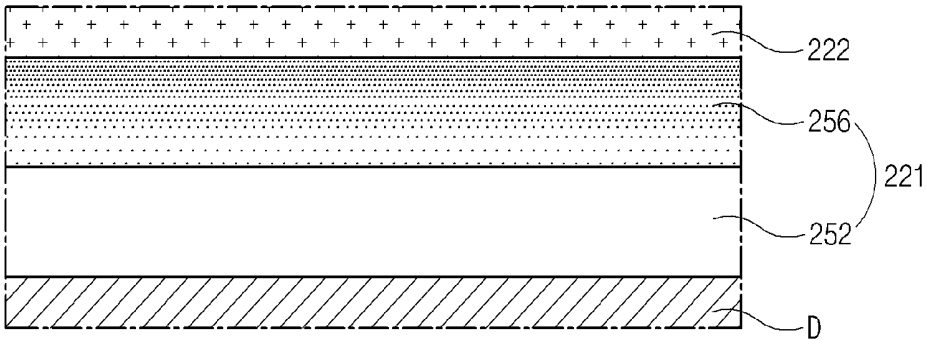


FIG. 7A

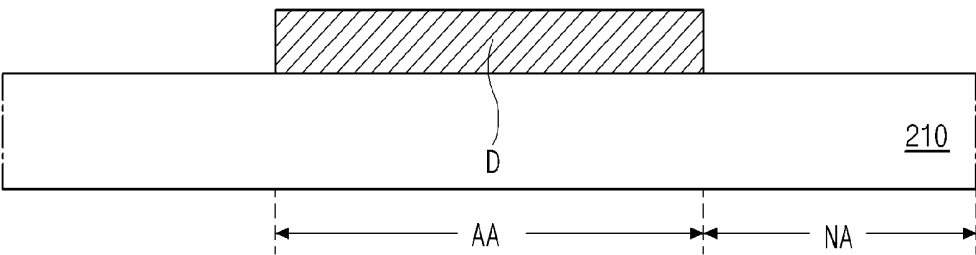


FIG. 7B

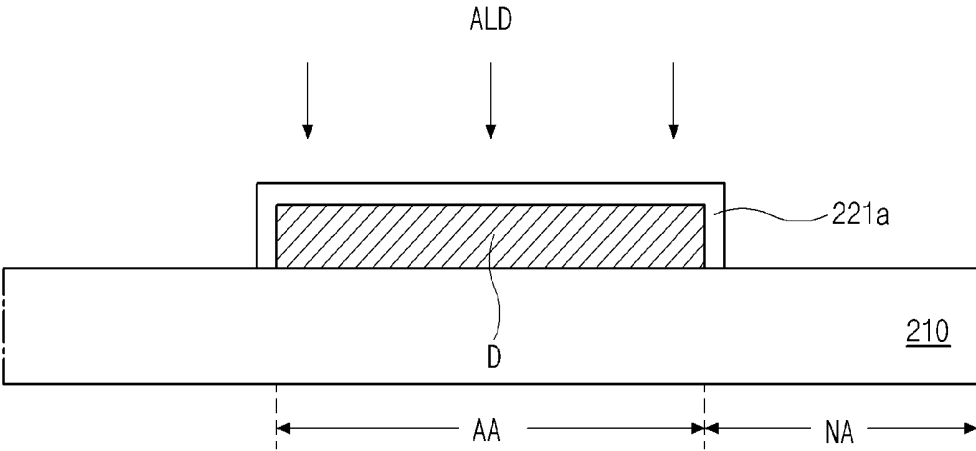


FIG. 7C

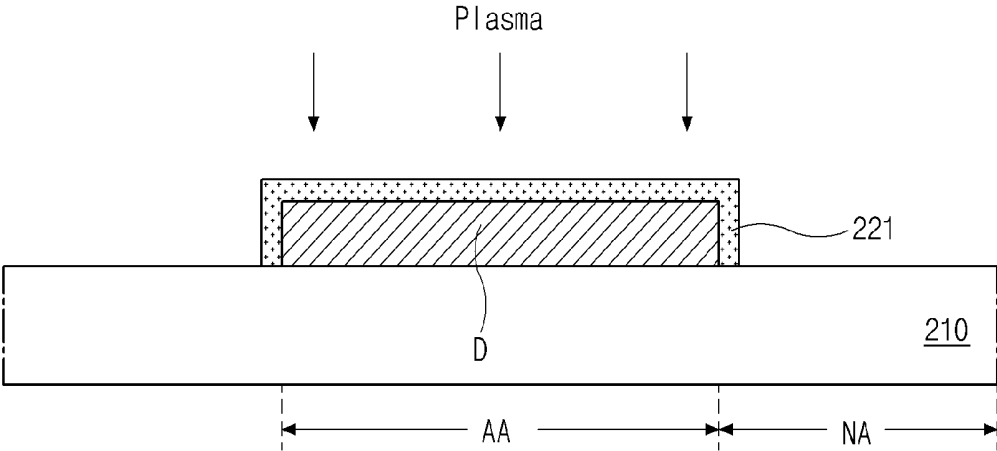


FIG. 7D

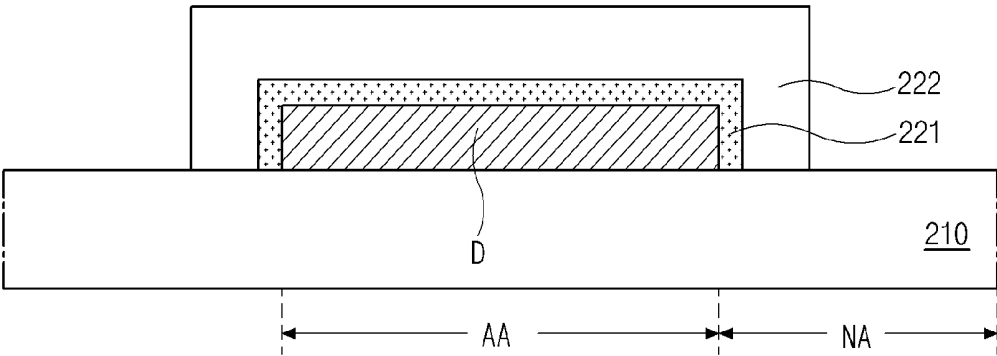
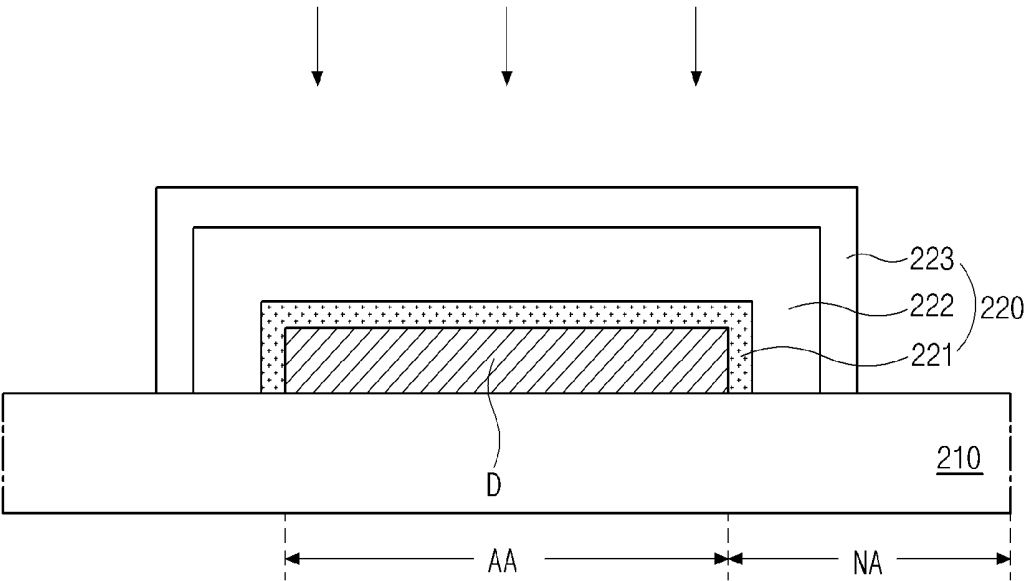


FIG. 7E

PECVD



**FLEXIBLE ORGANIC LIGHT EMITTING
DISPLAY DEVICE AND METHOD OF
FABRICATING THE SAME**

**CROSS-REFERENCE TO RELATED
APPLICATIONS**

[0001] The present application claims the benefit of Republic of Korea Patent Application No. 10-2015-0151286 filed in the Republic of Korea on Oct. 29, 2015, which is hereby incorporated by reference in its entirety.

BACKGROUND

[0002] Field of Technology

[0003] The present disclosure relates to an organic light emitting display (OLED) device and more particularly to a flexible OLED device that prevents damage of an organic emitting diode and a display quality degradation problem.

[0004] Discussion of the Related Art

[0005] As information technology and mobile communication technology have been developed, a display device capable of displaying a visual image has also been developed. Flat panel display devices, such as a liquid crystal display (LCD) device and an OLED device, are developed and used.

[0006] Among these flat panel display devices, since the OLED device has advantages in response time, contrast ratio, viewing angle, power consumption, and so on, the OLED device is widely developed.

[0007] An emitting diode including an organic emitting layer is susceptible to damage from moisture. To prevent moisture penetration into the emitting diode and to protect the emitting diode from external impacts, an encapsulation substrate of glass is attached onto the emitting diode.

[0008] Recently, flexible, rollable, or bendable display devices (hereinafter "flexible display device") have been introduced.

[0009] In the flexible OLED device, an encapsulation film including an inorganic layer and an organic layer is used instead of the encapsulation substrate. Namely, by using the encapsulation film for preventing moisture penetration into the emitting diode and to protect the emitting diode, the display device has a flexible property.

[0010] FIG. 1 is a schematic cross-sectional view of the related art OLED device.

[0011] As shown in FIG. 1, the OLED device 1 includes a flexible substrate 10, where a display area AA and a non-display area NA at a periphery of the display area AA are defined, an organic emitting diode D on or over the flexible substrate 10 and an encapsulation film 20 covering the organic emitting diode D.

[0012] The flexible substrate 10 may include polymer such as polyimide, and the organic emitting diode D is formed on or over the flexible substrate 10. The organic emitting diode D is positioned in the display area AA, and a driving part (not shown) for driving the organic emitting diode D is positioned in the non-display area NA.

[0013] Although not shown, the organic emitting diode D may include first and second electrodes facing each other and an organic emitting layer between the first and second electrodes. In addition, on the flexible substrate 10, a switching thin film transistor (TFT) as a switching element and a

driving TFT as a driving element are formed, and the first electrode of the emitting diode D is connected to the driving TFT.

[0014] The encapsulating film 20 covers the organic emitting diode D and corresponds to the display area AA and the non-display area NA. The encapsulating film 20 prevents damage to the emitting diode D under conditions of high temperature and high humidity.

[0015] In the encapsulation film 20, an inorganic layer and an organic layer are alternately stacked. For example, the encapsulation film 20 may have a triple-layered structure including a first inorganic layer 22 on the emitting diode D, an organic layer 24 on the first inorganic layer 22, and a second inorganic layer 26 on the organic layer 24.

[0016] A barrier film 30 is attached to the encapsulation film 20 using an adhesive layer 32.

[0017] However, when the flexible OLED device 1 is operated under a condition of high temperature and high humidity, the emitting diode D is still damaged resulting in problems in display quality and a lifetime of the flexible OLED device 1.

SUMMARY

[0018] Accordingly, the present disclosure is directed to a flexible OLED device and a method of fabricating the same that substantially obviate one or more of the problems due to limitations and disadvantages of the related art.

[0019] An object of the present disclosure is to provide a flexible OLED device and a method of fabricating the same being capable of preventing damage by moisture.

[0020] Another object of the present disclosure is to provide a flexible OLED device and a method of fabricating the same having a thin profile.

[0021] Additional features and advantages of the invention will be set forth in the description which follows, and in part will be apparent from the description, or may be learned by practice of the invention. The objectives and other advantages of the invention will be realized and attained by the structure particularly pointed out in the written description and claims hereof as well as the appended drawings.

[0022] To achieve these and other advantages and in accordance with the purpose of the present invention, as embodied and broadly described herein, a flexible organic light emitting display (OLED) device includes an organic emitting diode on a flexible substrate; and an encapsulation film covering the organic emitting diode and including a first inorganic layer and an organic layer, wherein an upper region of the first inorganic layer includes a first nitrogen-doped silicon oxide, and a lower region of the first inorganic layer includes a second nitrogen-doped silicon oxide or a nitrogen-nondoped silicon oxide.

[0023] In another aspect, a method of fabricating a flexible organic light emitting display (OLED) device includes: forming an organic emitting diode on a flexible substrate; forming a silicon oxide layer on the organic emitting layer; performing a plasma treating process onto the silicon oxide layer to form a first inorganic layer; and forming an organic layer on the first inorganic layer.

[0024] Embodiments also relate to a flexible organic light emitting display (OLED) device, that includes a flexible substrate, an organic emitting diode on the flexible substrate, and an encapsulation film covering the organic emitting diode. The encapsulation film includes a first inorganic layer

including a first material and encapsulates the organic emitting diode. At least a portion of the first inorganic layer also includes a dopant that increases surface energy of the doped first material compared to surface energy of the non-doped first material. An organic layer is on the first inorganic layer. **[0025]** Embodiments also relate to a method of fabricating a flexible organic light emitting display (OLED) device. An organic emitting diode is formed on a flexible substrate. A first layer of first material is formed on the organic emitting layer to encapsulate the organic emitting layer. A plasma treating process with gas containing a dopant is performed on the first layer to form a first inorganic layer having at least a portion including the dopant. The dopant increases surface energy of the doped first material compared to surface energy of the non-doped first material. An organic layer is formed on the first inorganic layer.

[0026] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and together with the description serve to explain the principles of the invention.

[0028] FIG. 1 is a schematic cross-sectional view of a related art OLED device.

[0029] FIG. 2 is a circuit diagram of one pixel region of an OLED device according to the present disclosure.

[0030] FIG. 3 is a schematic cross-sectional view of a flexible OLED device according to a first embodiment of the present disclosure.

[0031] FIG. 4 is a schematic cross-sectional view showing one pixel region with an organic emitting diode according to an embodiment of the present disclosure.

[0032] FIG. 5 is a schematic cross-sectional view of a flexible OLED device according to a second embodiment of the present disclosure.

[0033] FIGS. 6A and 6B are enlarged views of part "A" in FIG. 5 according to an embodiment of the present disclosure.

[0034] FIGS. 7A to 7E are schematic cross-sectional views illustrating a fabricating process of a flexible OLED device according to the second embodiment of the present disclosure.

DETAILED DESCRIPTION

[0035] In the related art flexible OLED device, the damage on the organic emitting diode occurs because of a crack in the encapsulating film by particles on the organic emitting diode.

[0036] The inorganic layer of the encapsulating film contacting the organic emitting diode is formed by a plasma enhanced chemical vapor deposition (PECVD) process. The inorganic layer by the PECVD process has bad step-coverage. Accordingly, the particles on the organic emitting diode are incompletely covered by the inorganic layer such that the crack is generated in the encapsulating film. As a result, the emitting diode is damaged by heat and/or moisture under a condition of high temperature and high humidity.

[0037] An upper portion of the particles on the organic emitting diode may be completely covered by increasing a thickness of the inorganic layer. However, even with the inorganic layer having a relatively high thickness, a lower portion of the particles and an interface between the particle and the organic emitting diode are still incompletely covered. As a result, the damage on the organic emitting diode still occurs.

[0038] In addition, with the inorganic layer having a relatively high thickness, the stress on the encapsulation film is increased such that the crack may be generated in the operation of folding, bending, or rolling and the flexibility of the flexible OLED device is decreased.

[0039] Accordingly, in the related art flexible OLED device, the crack is generated in the encapsulation film such that the organic emitting diode and/or the switching and driving TFTs are damaged resulting in problems in display quality and a lifetime of the flexible OLED device.

[0040] Reference will now be made in detail to the preferred embodiments, examples of which are illustrated in the accompanying drawings.

[0041] FIG. 2 is a circuit diagram of one pixel region of an OLED device according to the present disclosure.

[0042] Referring to FIG. 2, an OLED device includes a gate line "GL," a data line "DL," a power supply line "PL," a switching thin film transistor (TFT) "Ts," a driving TFT "Td," a storage capacitor "Cst," and at least one organic emitting diode "D." The gate line "GL" and the data line "DL" cross each other to define a pixel region "P."

[0043] The switching TFT "Ts" is connected to the gate line and data line "GL" and "DL," and the driving TFT "Td" and the storage capacitor "Cst" are connected to the switching TFT "Ts" and the power line "PL." The organic emitting diode "D" is connected to the driving TFT "Td."

[0044] When the switching TFT "Ts" is turned on by a gate signal applied through the gate line "GL," a data signal from the data line "DL" is applied to the gate electrode of the driving TFT "Td" and an electrode of the storage capacitor "Cst." When the driving TFT "Td" is turned on by the data signal, an electric current is supplied to the organic emitting diode "D" from the power line "PL." As a result, the organic emitting diode "D" emits light. In this case, when the driving TFT "Td" is turned on, a level of an electric current applied from the power supply line "PL" to the organic emitting diode "D" is determined such that the organic emitting diode "D" can produce a gray scale. The storage capacitor "Cst" serves to maintain the voltage of the gate electrode of the driving TFT "Td" when the switching TFT "Ts" is turned off. Accordingly, even if the switching TFT "Ts" is turned off, a level of an electric current applied from the power supply line "PL" to the organic emitting diode "D" is maintained to the next frame.

[0045] FIG. 3 is a schematic cross-sectional view of a flexible OLED device according to a first embodiment of the present disclosure, and FIG. 4 is a schematic cross-sectional view showing one pixel region with an organic emitting diode according to an embodiment of the present disclosure.

[0046] As shown in FIGS. 3 and 4, a flexible OLED device 100 according to the first embodiment of the present invention includes a flexible substrate 110, where a display area AA and a non-display area NA at peripheries of the display area AA are defined, an organic emitting diode D on the flexible substrate 110, and an encapsulation film 120 covering the organic emitting diode D. A first inorganic layer

121 as a lowest layer of the encapsulation film **120** is formed by an atomic layer deposition (ALD) method.

[0047] The flexible substrate **110** may be formed of polymer such as polyimide. However, it is not limited thereto.

[0048] Although not shown, a buffer layer, which is formed of an inorganic insulating material, such as silicon oxide or silicon nitride, may be formed on the flexible substrate **110**.

[0049] On the flexible substrate **110**, a driving TFT Td and an organic emitting diode D are formed. In addition, a gate line (not shown) and a data line (not shown), which cross each other to define a pixel region, a power line (not shown), which is parallel to and spaced apart from the gate line or the data line, a switching TFT (not shown), which is connected to the gate and data lines, a storage capacitor (not shown), which is connected to the power line and an electrode of the switching TFT, are further formed on the flexible substrate **110**.

[0050] The driving TFT Td is connected to the switching TFT and includes a semiconductor layer **152**, a gate electrode **160**, a source electrode **170**, and a drain electrode **172**.

[0051] The semiconductor layer **152** is disposed on the flexible substrate **110** and may include an oxide semiconductor material or polycrystalline silicon.

[0052] When the semiconductor layer **152** includes the oxide semiconductor material, a light-shielding pattern (not shown) may be formed under the semiconductor layer **152**. The light to the semiconductor layer **152** is shielded or blocked by the light-shielding pattern such that thermal degradation of the semiconductor layer **152** can be prevented. On the other hand, when the semiconductor layer **152** includes polycrystalline silicon, impurities may be doped into both sides of the semiconductor layer **152**.

[0053] A gate insulating layer **154** is formed on an entire surface of the flexible substrate **110** including the semiconductor layer **152**. The gate insulating layer **154** may be formed of an inorganic insulating material such as silicon oxide or silicon nitride. For example, when the semiconductor layer **152** includes the oxide semiconductor material, the gate insulating layer **154** may be formed of silicon oxide.

[0054] A gate electrode **160**, which is formed of a conductive material, e.g., metal, is formed on the gate insulating layer **154** to correspond to a center of the semiconductor layer **152**. The gate electrode **160** is connected to the switching TFT.

[0055] In FIG. 4, the gate insulating layer **154** is formed on the entire surface of the flexible substrate **110**. Alternatively, the gate insulating layer **154** may be patterned to have the same shape as the gate electrode **160**.

[0056] An interlayer insulating layer **162**, which is formed of an insulating material, is formed on an entire surface of the flexible substrate **110** including the gate electrode **160**. The interlayer insulating layer **162** may 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.

[0057] The interlayer insulating layer **162** includes first and second contact holes **164** and **166** exposing both sides of the semiconductor layer **152**. The first and second contact holes **164** and **166** are positioned at both sides of the gate electrode **160** to be spaced apart from the gate electrode **160**.

[0058] In FIG. 4, the first and second contact holes **164** and **166** extend into the gate insulating layer **154**. Alternatively, when the gate insulating layer **154** is patterned to

have the same shape as the gate electrode **160**, there may be no first and second contact holes **164** and **166** in the gate insulating layer **154**.

[0059] A source electrode **170** and a drain electrode **172**, which are formed of a conductive material, e.g., metal, are formed on the interlayer insulating layer **162**. The drain electrode **172** and the source electrode **170** are spaced apart from each other with respect to the gate electrode **160** and respectively contact both sides of the semiconductor layer **152** through the first and second contact holes **164** and **166**. The source electrode **170** is connected to the power line (not shown).

[0060] The semiconductor layer **152**, the gate electrode **160**, the source electrode **170**, and the drain electrode **172** constitute the driving TFT Td. In FIG. 4, the gate electrode **160**, the source electrode **170**, and the drain electrode **172** are positioned over the semiconductor layer **152**. Namely, the driving TFT Td has a coplanar structure.

[0061] Alternatively, in the driving TFT Td, the gate electrode **160** may be positioned under the semiconductor layer **152**, and the source and drain electrodes **170**, **172** may be positioned over the semiconductor layer **152** such that the driving TFT Td may have an inverted staggered structure. In this instance, the semiconductor layer **152** may include amorphous silicon.

[0062] The switching TFT (not shown) may have substantially the same structure as the driving TFT Td.

[0063] A passivation layer **174**, which includes a drain contact hole **176** exposing the drain electrode **172** of the driving TFT Td, is formed to cover the driving TFT Td.

[0064] A first electrode **180**, which is connected to the drain electrode **172** of the driving TFT Td through the drain contact hole **176**, is separately formed on the passivation layer **174** in each pixel region. The first electrode **180** may be an anode and may be formed of a conductive material having a relatively high work function. For example, the first electrode **180** may be formed of a transparent conductive material such as indium-tin-oxide (ITO) or indium-zinc-oxide (IZO).

[0065] When the flexible OLED device **100** is operated in a top-emission type, a reflection electrode or a reflection layer may be formed under the first electrode **180**. For example, the reflection electrode or the reflection layer may be formed of aluminum-palladium-copper (APC) alloy.

[0066] A bank layer **186**, which covers edges of the first electrode **180**, is formed on the passivation layer **174**. A center of the first electrode **180** in the pixel region is exposed through an opening of the bank layer **186**.

[0067] An organic emitting layer **182** is formed on the first electrode **180**. The organic emitting layer **182** may have a single-layered structure of an emitting material layer formed of an emitting material. Alternatively, to improve emitting efficiency, the organic emitting layer **182** may have a multi-layered structure including a hole injection layer, a hole transporting layer, the emitting material layer, an electron transporting layer, and an electron injection layer sequentially stacked on the first electrode **180**.

[0068] A second electrode **184** is formed over the flexible substrate **110** including the organic emitting layer **182**. The second electrode **184** is positioned at an entire surface of the display area AA. The second electrode **184** may be a cathode and may be formed of a conductive material having a

relatively low work function. For example, the second electrode **184** may be formed of aluminum (Al), magnesium (Mg) or Al—Mg alloy.

[0069] The first electrode **180**, the organic emitting layer **182**, and the second electrode **184** constitute the organic emitting diode D.

[0070] An encapsulation film **120** is formed on the second electrode **184** to prevent penetration of moisture into the light emitting diode D.

[0071] The encapsulation film **120** has a triple-layered structure of a first inorganic layer **121**, an organic layer **122**, and a second inorganic layer **123**. However, it is not limited thereto. For example, the encapsulation film **120** may further include an organic layer on the second inorganic layer **123** to have a quadruple-layered structure or may further include an organic layer and an inorganic layer on the second inorganic layer **123** to have a five-layered structure.

[0072] The first inorganic layer **121** contacts the light emitting diode D and is formed by the ALD process to have excellent step-coverage. For example, the first inorganic layer **121** may be formed of silicon oxide (SiOx:H).

[0073] Namely, by performing the ALD process using a precursor, such as bis(ethylmethylamino)silane, diisopropylaminosilane, trimethylsilylazide or tris(dimethylamino)silane, O₂ reaction gas and N₂ purge gas, the first organic layer **121** of silicon oxide is formed. The first inorganic layer **121** may have a thickness of about 0.01 to 0.1 micrometers, and beneficially, about 0.05 micrometers.

[0074] The organic layer **122** is formed on the first inorganic layer **121**. The stress applied to the first inorganic layer **121** can be reduced by the organic layer **122**. For example, the organic layer **122** may be formed of an acryl-based material or an epoxy-based material.

[0075] The second inorganic layer **123** is formed on the organic layer **122**. The second inorganic layer **123** is formed by the PECVD process such that a thickness of the second inorganic layer **123** is larger than that of the first inorganic layer **121**. The penetration of moisture into the light emitting diode D is further prevented by the second inorganic layer **123**.

[0076] For example, the second inorganic layer **123** may be formed of silicon oxide (SiOx:H), silicon nitride (SiNx:H), or siliconoxynitride (SiON). The second inorganic layer **123** may have a thickness of about 0.1 to 2 micrometers, and beneficially, about 1 micrometer.

[0077] A barrier film **130** further minimizing the moisture penetration and protecting the encapsulation film **120** may be attached onto the encapsulation film **120** using an adhesion layer **140**. For example, the adhesion layer **140** may be a pressure sensitive adhesive. The penetration of moisture is further prevented by the barrier film **130**, and the encapsulation film **120** is protected by the barrier film **130**. The barrier film **130** and the adhesion layer **140** may be omitted.

[0078] Alternatively, a touch panel (not shown) may be attached on the encapsulation film **120** using the adhesion layer **140**, and/or a polarization plate (not shown) may be further attached on an outer side of the encapsulation film **120** to reduce ambient light reflection and increase a contrast ratio. In this instance, the polarization plate may be a circular polarization plate.

[0079] As mentioned above, in the flexible OLED device **100** according to the first embodiment of the present inven-

tion, the first inorganic layer **121** as a lowest layer of the encapsulation film **120** is formed by the ALD process to have excellent step-coverage.

[0080] Accordingly, even if there are particles on the organic emitting diode D, the particles are completely covered with the first inorganic layer **121** such that there is no crack in the encapsulation film **120**. As a result, the damages on an element in the display area AA, e.g., the organic emitting diode D, by moisture penetration are minimized or prevented.

[0081] In addition, since the first inorganic layer **121**, which is formed by the ALD process, has a relatively small thickness with excellent step-coverage, a thickness of the encapsulation film **120** is not increased.

[0082] Namely, the flexible OLED device **100** of the present disclosure has improved displaying quality and lifetime without increasing the thickness.

[0083] However, with the first inorganic layer **121**, which is formed of silicon oxide by the ALD process, there is a problem in a coating property or characteristic of the organic layer **122**. As a result, there is a stain or mura problem such that the displaying quality of the flexible OLED device **100** is degraded. In addition, moisture is penetrated through an interface between the first inorganic layer **121** and the organic layer **122** such that the organic emitting diode D is damaged.

[0084] FIG. 5 is a schematic cross-sectional view of a flexible OLED device according to a second embodiment of the present disclosure, and FIGS. 6A and 6B are enlarged views of part "A" in FIG. 5 according to an embodiment of the present disclosure.

[0085] Referring to FIG. 5, a flexible OLED device **200** according to the second embodiment of the present disclosure includes a flexible substrate **210**, where a display area AA and a non-display area NA at peripheries of the display area AA are defined, at least one organic emitting diode D on the flexible substrate **210**, and an encapsulation film **220** covering the at least one organic emitting diode D and including first and second inorganic layers **221** and **223** and an organic layer **222**. The first inorganic layer **221** as a lowest layer of the encapsulation film **220** is formed by an atomic layer deposition (ALD) method and includes at least a portion including a dopant that increases surface energy of the doped material of the first inorganic layer **221** compared to that of the non-doped material. In one particular embodiment referred throughout this application, the material of the first inorganic layer **221** is silicon oxide, and the dopant is nitrogen, and at least a portion of the first inorganic layer **221** includes nitrogen-doped silicon oxide (SixOyNz:H).

[0086] In one instance, at least the top surface of the first inorganic layer **221** includes the dopant. In one instance, the dopant may have a concentration gradient in the first inorganic layer **221**. The concentration gradient may be discrete or continuous such that the concentration of the dopant increases from portions of the first inorganic layer **221** closer to the organic emitting diode D towards portions of the first inorganic layer **221** farther away from the organic emitting diode D, such as the top surface of the first inorganic layer **221**.

[0087] The flexible substrate **210** may be formed of polymer such as polyimide. However, it is not limited thereto.

[0088] On the flexible substrate **210**, a driving TFT Td (of FIG. 4) and an organic emitting diode D connected to the driving TFT Td are formed.

[0089] As illustrated with FIG. 4, the driving TFT Td includes the semiconductor layer 152, the gate electrode 160, the source electrode 170, and the drain electrode 172, and the organic emitting diode D includes the first electrode 180, which is connected to the drain electrode 172, the second electrode 184, which faces the first electrode 180, and the organic emitting layer 182 therebetween.

[0090] The encapsulation film 220 is formed on the organic emitting diode D to prevent the moisture penetration into the organic emitting diode D. Namely, the encapsulation film 220 covers the organic emitting diode D and extends to the non-display area NA.

[0091] The encapsulation film 220 has a triple-layered structure of a first inorganic layer 221, an organic layer 222, and a second inorganic layer 223. However, it is not limited thereto. For example, the encapsulation film 220 may further include an organic layer on the second inorganic layer 223 to have a quadruple-layered structure or may further include an organic layer and an inorganic layer on the second inorganic layer 223 to have a five-layered structure. In addition, without the second inorganic layer 223, the encapsulation film 220 may have a double-layered structure of the first inorganic layer 221 and the organic layer 222.

[0092] The first inorganic layer 221 contacts or is adjacent to the organic emitting diode D. An upper portion of the first inorganic layer 221 includes a dopant that increases surface energy of the doped material of the first inorganic layer 221 compared to that of non-doped material, and a lower portion of the first inorganic layer 221 closer to the organic emitting diode D than the upper portion includes the dopant having a concentration lower than the concentration of the dopant in the upper portion, or includes non-doped material. The upper portion may be a top surface of the first inorganic layer 221.

[0093] In one embodiment, when silicon oxide is the material of the first inorganic layer 221, and when the dopant is nitrogen, the upper portion includes a nitrogen-doped silicon oxide (SixOyNz:H), and a lower portion of the first inorganic layer 221 includes a nitrogen-doped silicon oxide (SixOyNz:H), where a nitrogen concentration in the lower portion is smaller than that in the upper portion, or non-doped silicon oxide.

[0094] Namely, the chemical formula in the upper portion of the first inorganic layer 221 may be $\text{Si}_{x1}\text{O}_{y1}\text{N}_{z1}:\text{H}$, and that of the lower portion of the first inorganic layer 221 may be $\text{Si}_{x2}\text{O}_{y2}\text{N}_{z2}:\text{H}$. The unknowns $x1$, $x2$, $y1$, $y2$, $z1$, and $z2$ meet the following:

[0095] $x1 \leq x2$, $y1 < y2$, and $z1 > z2$.

[0096] In addition, the unknowns $x1$, $x2$, $y1$, $y2$, $z1$, and $z2$ further meet the following:

[0097] $0.8 \leq x1$, $x2 \leq 1.2$, $1.4 \leq y1$, $y2 \leq 1.9$, $0 < z1 \leq 0.5$, and $0 \leq z2 \leq 0.5$.

[0098] For example, by depositing a silicon oxide layer by the ALD process and performing a plasma treating process with NH_3 gas, N_2O gas, or N_2 gas onto the silicon oxide layer, the upper portion of the first inorganic layer 221 is doped by nitrogen. In this instance, the nitrogen is doped or not doped into the lower portion of the second inorganic layer 221.

[0099] In one instance, when the dopant is doped throughout the first inorganic layer 221, the dopant concentration in the upper portion is greater than that in the lower portion. Namely, the dopant has a concentration gradient in the first inorganic layer 221. The concentration gradient in the first

inorganic layer 221 may be discrete or continuous such that the concentration of the dopant increases from portions of the first inorganic layer 221 closer to the organic emitting diode D towards portions farther away from the organic emitting diode D. For example, when the dopant is doped throughout the first inorganic layer 221, the concentration of the dopant may increase continually or gradually from the bottom surface of the first inorganic layer 221 adjacent to the organic emitting diode D to the top surface of the first inorganic layer 221. The top surface of the first inorganic layer 221 may have the highest concentration of the dopant in the first inorganic layer 221.

[0100] As a result, the upper portion of the first inorganic layer 221 has a surface energy being greater than the lower portion of the first inorganic layer 221.

[0101] On the other hand, when the material of the first inorganic layer 221 is silicon oxide, and the dopant is nitrogen, and the plasma treating process is performed using the N_2 gas, a high temperature condition is required. Namely, when the N_2 gas plasma treating process is performed under a low temperature condition, the desired surface modification of the silicon oxide layer is not provided. To prevent the damage on the organic emitting diode D by the high temperature process and provide the desired surface modification of the silicon oxide layer, it is preferred to perform the plasma treating process using NH_3 gas or N_2O gas.

[0102] The first inorganic layer 221 may have a thickness of about 0.01 to 0.1 micrometers, and beneficially, about 0.05 micrometers.

[0103] The organic layer 222 is formed on the first inorganic layer 221. The stress applied to the first inorganic layer 221 can be reduced by the organic layer 222. For example, the organic layer 222 may be formed of an acryl-based material or an epoxy-based material and may be formed by one of an inkjet coating process, a slit coating process, and a bar coating process.

[0104] The second inorganic layer 223 is formed on the organic layer 222. The second inorganic layer 223 is formed by the PECVD process such that a thickness of the second inorganic layer 223 is larger than that of the first inorganic layer 221. For example, the second inorganic layer 223 may be formed of silicon oxide (SiOx:H), silicon nitride (SiNx:H), or siliconoxynitride (SiON). The second inorganic layer 223 may have a thickness of about 0.1 to 2 micrometers, and beneficially, about 1 micrometer.

[0105] Alternatively, the second inorganic layer 223 may be formed by the ALD process and may include silicon oxide (SiOx:H).

[0106] A barrier film 230 further minimizing the moisture penetration and protecting the encapsulation film 220 may be attached onto the encapsulation film 220 using an adhesion layer 240. For example, the adhesion layer 240 may be a pressure sensitive adhesive. The penetration of moisture is further prevented by the barrier film 230, and the encapsulation film 220 is protected by the barrier film 230. The barrier film 230 and the adhesion layer 240 may be omitted.

[0107] Alternatively, a touch panel (not shown) may be attached on the encapsulation film 220 using the adhesion layer 240, and/or a polarization plate (not shown) may be further attached on an outer side of the encapsulation film 220 to reduce ambient light reflection and increase a contrast ratio. In this instance, the polarization plate may be a circular polarization plate.

[0108] As mentioned above, in the flexible OLED device 200 according to the second embodiment of the present invention, the first inorganic layer 221 as a lowest layer of the encapsulation film 220 is formed by the ALD process to have excellent step-coverage.

[0109] Accordingly, even if there are particles on the organic emitting diode D, the particles are completely covered with the first inorganic layer 221 such that there is no crack in the encapsulation film 220. As a result, the damages on an element in the display area AA, e.g., the organic emitting diode D, by moisture penetration are minimized or prevented.

[0110] In addition, the upper portion of the first inorganic layer 221 of the encapsulation film 220 includes a nitrogen-doped silicon oxide such that a coating property of the organic layer 222 on the first inorganic layer 221 is improved.

[0111] There is no precursor for forming a silicon nitride layer and a siliconoxynitride layer by the ALD process and only the silicon oxide layer can be formed by the ALD process. However, when the first inorganic layer 221 of silicon oxide is formed by the ALD process without a plasma treating process, the coating property of the organic layer 222 on the first inorganic layer 221 is degraded.

[0112] However, when a dopant, such as nitrogen, is doped into a silicon oxide layer formed by the ALD process, the surface energy of the first inorganic layer 221 is increased such that the coating property of the organic layer 222 on the first inorganic layer 221 is improved. As a result, the displaying quality degradation problem in the OLED display device is prevented.

[0113] Referring to FIG. 6A, the first inorganic layer 221 includes or is divided into a lower region 252 adjacent to the organic emitting diode D, an upper region 256 adjacent to the organic layer 222, and an intermediate region 254 between the lower and upper regions 252 and 256.

[0114] In this instance, a dopant concentration in the intermediate region 254 is higher than that in the lower region 252 and smaller than that in the upper region 256. Namely, the dopant is doped throughout regions of the first inorganic layer 221 in a vertical direction, and the dopant concentration may be gradually increased from the lower region 252 to the upper region 256.

[0115] In other embodiments, the first inorganic layer 221 may include or may be divided into fewer or more regions than an upper region 256, an intermediate region 254, and a lower region 252. For example, the first inorganic layer 221 may be divided into a lower region and an upper region, in which a dopant concentration in the upper region is higher than that in the lower region. As another example, the first inorganic layer 221 may be divided into 4 or more regions in which the dopant concentration sequentially increases from the lower region to the upper region.

[0116] Referring to FIG. 6B, the first inorganic layer 221 includes or is divided into a lower region 252 adjacent to the organic emitting diode D and an upper region 256 adjacent to the organic layer 222.

[0117] In this instance, material in the lower region 252 is not doped with a dopant, and the dopant is doped into the upper region 256. In addition, in the upper region 256, the dopant concentration may be gradually increased from a bottom portion to a top portion of the upper region 256 to have a concentration gradient. For example, the dopant concentration may have a gradient from the top surface of

the first inorganic layer 221 to a bottom portion of the upper region 256. In other instances, the upper region 256 may have a uniform concentration of the dopant, or may be divided into two or more regions having different dopant concentrations.

[0118] Namely, in the flexible OLED device 200 according to the second embodiment of the present invention, a top surface of the first inorganic layer 221 includes a dopant that increases surface energy of the doped material of the first inorganic layer 221 compared to that of non-doped material, and the dopant may have a concentration gradient in the first inorganic layer 221.

[0119] Accordingly, the surface energy of the first inorganic layer 221 is increased such that the coating property of the organic layer 222 on the first inorganic layer 221 is improved. As a result, the film uniformity of the organic layer 222 is improved, and the displaying quality degradation problem in the OLED display device is prevented.

[0120] Namely, since the first inorganic layer 221 by the ALD process has excellent step-coverage and a thin profile and the coating property of the organic layer 222 is improved, the flexible OLED device 200 having a thin profile without the displaying quality degradation and the damage on the organic emitting diode D is provided.

[0121] FIGS. 7A to 7E are schematic cross-sectional views illustrating a fabricating process of a flexible OLED device according to the second embodiment of the present disclosure.

[0122] As shown in FIG. 7A, a driving TFT (not shown) is formed on the flexible substrate 210, and the organic emitting diode D is formed over the flexible substrate 210 in the display area AA.

[0123] Referring to FIG. 4, by depositing and patterning an oxide semiconductor material or polysilicon, the semiconductor layer 152 of the driving TFT DTr is formed on the flexible substrate 110. In addition, a semiconductor layer of the switching TFT is formed on the flexible substrate.

[0124] Next, an inorganic insulating material, e.g., silicon oxide or silicon nitride, is deposited to form the gate insulating layer 154 on the semiconductor layer 152.

[0125] Next, by forming and patterning a first metal layer (not shown) on the gate insulating layer 154, the gate electrode 160 of the driving TFT DTr corresponding to the center of the semiconductor layer 152 is formed. In addition, a gate electrode of the switching TFT, a gate line and a power line is formed.

[0126] Next, the interlayer insulating layer 162 is formed on the gate electrode 160, and a mask process is performed onto the interlayer insulating layer 162 and the gate insulating layer 154 to form the first and second contact holes 164 and 166 exposing both sides of the semiconductor layer 152. For example, the interlayer insulating layer 162 may 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.

[0127] Next, by forming and patterning a second metal layer (not shown) on the interlayer insulating layer 162, the drain electrode 172 and the source electrode 170, which respectively contact the sides of the semiconductor layer 152 through the first and second contact holes 164 and 166, are formed. In addition, source and drain electrodes of the switching TFT and a data line are formed.

[0128] Next, the passivation layer 174 is formed on the source and drain electrodes 170 and 172, and a mask process

is performed onto the passivation layer 174 to form a drain contact hole 176 exposing the drain electrode 172. For example, the passivation layer 174 may be formed of an organic insulating material, e.g., benzocyclobutene or photo-acryl.

[0129] Next, a transparent conductive material layer (not shown) is formed by depositing a transparent conductive material, e.g., ITO or IZO, and is patterned by a mask process to form the first electrode 180. The first electrode 180 is connected to the drain electrode 172 of the driving TFT DTr through the drain contact hole 176.

[0130] Next, the bank layer 186, which covers edges of the first electrode 180, is formed on the passivation layer 174.

[0131] Next, the organic emitting layer 182 is formed on the first electrode 180.

[0132] Next, a metallic material, e.g., aluminum (Al), magnesium (Mg) or Al—Mg alloy, is deposited to form the second electrode 184. As a result, the driving TFT DTr and the organic emitting diode D, which is electrically connected to the driving TFT DTr, are formed on or over the flexible substrate 110.

[0133] Next, as shown in FIG. 7B, a silicon oxide layer 221a covering the organic emitting diode D is formed by the ALD process.

[0134] For example, in the ALD process, a precursor, such as bis(ethylmethylamino)silane, diisopropylaminosilane, trimethylsilylazide or tris(dimethylamino)silane, O₂ reaction gas and N₂ purge gas are used to form the silicon oxide layer 221a. The silicon oxide layer 221a may have a thickness of about 0.01 to 0.1 micrometers.

[0135] Next, as shown in FIG. 7C, a surface of the silicon oxide layer 221a (of FIG. 7B) is modified by a plasma treating process using a gas containing a dopant that increases surface energy of the doped material of the layer 221a compared to that of non-doped material. In one embodiment, when the material of the layer 221a is silicon oxide and the dopant is nitrogen, the surface of the silicon oxide layer 221a is modified by a plasma treating process using N₂, N₂O gas or NH₃ gas such that the first inorganic layer 221 is formed. For example, the plasma treating process may be performed under a condition of about 2800 to 3400 W for about 10 to 20 seconds.

[0136] As a result, the dopant is doped throughout the first inorganic layer 221 as shown in FIG. 6A, or the dopant is doped into the upper region except the lower region of the first inorganic layer 221 as shown in FIG. 6B.

[0137] Namely, a top surface of the first inorganic layer 221 includes the dopant, and the dopant has a concentration gradient in the first inorganic layer 221. Accordingly, the top surface of the first inorganic layer 221 has the surface energy being greater than the silicon oxide layer 221a (of FIG. 7B).

[0138] Next, as shown in FIG. 7D, the organic layer 222 is formed by coating an organic material, e.g., an acryl-based material or an epoxy-based material, on the first inorganic layer 221. For example, the organic layer 222 may be formed by an inkjet coating process.

[0139] Next, as shown in FIG. 7E, the PECVD process is performed to form the second inorganic layer 223 of silicon oxide (SiO_x:H), silicon nitride (SiN_x:H), or siliconoxynitride (SiON) on the organic layer 222. Alternatively, the second inorganic layer 223 may be formed by the ALD process and may include silicon oxide (SiO_x:H).

[0140] As mentioned above, since a dopant that increases surface energy is doped for the surface modification of the

silicon oxide layer (the first inorganic layer 221), the surface energy of the first inorganic layer 221 is increased and a coating property of the organic layer 222 on the first inorganic layer 221 is improved. Accordingly, the flexible OLED device 200 having a thin profile without the displaying quality degradation and the damage on the organic emitting diode D is provided.

[0141] It will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the spirit or scope of the invention. Thus, it is intended that the present invention cover the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. A flexible organic light emitting display (OLED) device, comprising:

a flexible substrate;

an organic emitting diode on the flexible substrate; and
an encapsulation film covering the organic emitting diode, the encapsulation film including:

a first inorganic layer comprising a first material and encapsulating the organic emitting diode, at least a portion of the first inorganic layer also comprising a dopant that increases surface energy of the doped first material compared to surface energy of the non-doped first material; and

an organic layer on the first inorganic layer.

2. The flexible OLED device of claim 1, wherein the first material is silicon oxide, and the dopant is nitrogen.

3. The flexible OLED device of claim 1, wherein the portion is a top surface of the first inorganic layer.

4. The flexible OLED device of claim 1, wherein within said portion of the first inorganic layer, a concentration of the dopant in a first portion of the first inorganic layer is higher than a concentration of the dopant in a second portion of the first inorganic layer closer to the organic emitting diode than the first portion.

5. The flexible OLED device of claim 4, wherein a concentration of the dopant in a third portion of the first inorganic layer between the first portion and the second portion is higher than the concentration in the second portion but lower than the concentration in the first portion.

6. The flexible OLED device of claim 4, wherein the second portion of the first inorganic layer includes the non-doped first material.

7. The flexible OLED device of claim 4, wherein the first material is silicon oxide and the dopant is nitrogen, and when a chemical formula for the doped first material in the first portion is Si_{x1}O_{y1}N_{z1}:H, and a chemical formula for the doped first material in the second portion is Si_{x2}O_{y2}N_{z2}:H, wherein x1≤x2, y1<y2, and z1>z2.

8. The flexible OLED device of claim 7, wherein 0.8≤x1, x2≤1.2, 1.4≤y1, y2≤1.9, 0<z1≤0.5, and 0≤z2≤0.5.

9. The flexible OLED device of claim 1, wherein the dopant has a concentration gradient in the portion of the first inorganic layer.

10. The flexible OLED device of claim 1, wherein the encapsulation film further includes a second inorganic layer covering the organic layer and including silicon oxide, silicon nitride, or siliconoxynitride.

11. The flexible OLED device of claim 10, wherein the second inorganic layer is thicker than the first inorganic layer.

12. The flexible OLED device of claim 1, further comprising:

a thin film transistor between the flexible substrate and the organic emitting diode; and

a passivation layer between the thin film transistor and the organic emitting diode,

wherein the organic emitting diode is electrically connected to the thin film transistor.

13. A method of fabricating a flexible organic light emitting display (OLED) device, comprising:

forming an organic emitting diode on a flexible substrate;

forming a first layer of first material on the organic emitting layer to encapsulate the organic emitting layer;

performing a plasma treating process with gas containing a dopant on the first layer to form a first inorganic layer having at least a portion comprising the dopant, wherein the dopant increases surface energy of the doped first material compared to surface energy of the non-doped first material; and

forming an organic layer on the first inorganic layer.

14. The method of claim 13, wherein the first material is silicon oxide, and the first layer of silicon oxide is formed by an atomic layer deposition (ALD) process.

15. The method of claim 14, wherein the atomic layer deposition process uses a precursor selected from bis(eth-

ylmethylamino)silane, diisopropylaminosilane, trimethylsilylazide, and tris(dimethylamino)silane, O₂ reaction gas, and N₂ purge gas.

16. The method of claim 13, wherein the dopant is nitrogen.

17. The method of claim 16, wherein the gas containing the dopant is N₂O gas or NH₃ gas.

18. The method of claim 13, wherein a concentration of the dopant in a first portion of the first inorganic layer is higher than a concentration of the dopant in a second portion of the first inorganic layer closer to the organic emitting diode than the first portion.

19. The method of claim 13, further comprising forming a second inorganic layer covering the organic layer, the second inorganic layer including silicon oxide, silicon nitride, or siliconoxynitride.

20. The method of claim 13, wherein the first material is silicon oxide, and the first layer of silicon oxide is formed by an atomic layer deposition (ALD) process and a second inorganic layer is formed by a plasma enhanced chemical vapor deposition (PECVD) process such that the second inorganic layer is thicker than the first inorganic layer.

* * * * *

专利名称(译)	柔性有机发光显示装置及其制造方法		
公开(公告)号	US20170125732A1	公开(公告)日	2017-05-04
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[标]申请(专利权)人(译)	乐金显示有限公司		
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其他公开文献	US10468626		
外部链接	Espacenet USPTO		

摘要(译)

柔性有机发光显示 (OLED) 器件包括在柔性基板上的有机发光二极管 , 覆盖有机发光二极管并包括第一无机层和有机层的封装膜。第一无机层由第一材料形成 , 并且第一无机层的至少一部分包括掺杂剂 , 与非掺杂材料相比 , 掺杂剂增加掺杂材料的表面能。

