US009954040B2

(12) **United States Patent**
Lee et al.

(10) **Patent No.: US 9,954,040 B2**
(45) **Date of Patent: *Apr. 24, 2018**

(54) **ORGANIC LIGHT-EMITTING DISPLAY APPARATUS**

(71) Applicant: **SAMSUNG DISPLAY CO., LTD.**, Yongin-si, Gyeonggi-do (KR)

(72) Inventors: **Duckjung Lee**, Yongin-si (KR); **Taewook Kang**, Yongin-si (KR); **Jaesik Kim**, Yongin-si (KR)

(73) Assignee: **SAMSUNG DISPLAY CO., LTD.**, Yongin, Gyeonggi-Do (KR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **15/490,665**

(22) Filed: **Apr. 18, 2017**

(65) **Prior Publication Data**

US 2017/0221973 A1 Aug. 3, 2017

Related U.S. Application Data

(63) Continuation of application No. 14/797,295, filed on Jul. 13, 2015, now Pat. No. 9,653,698.

(30) **Foreign Application Priority Data**

Oct. 22, 2014 (KR) 10-2014-0143593

(51) **Int. Cl.**
H01L 27/32 (2006.01)
H01L 51/50 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01L 27/3246*** (2013.01); ***H01L 27/3211*** (2013.01); ***H01L 51/001*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H01L 27/3246; H01L 51/524; H01L 51/5253; H01L 51/5228; H01L 27/3211;
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

9,653,698 B2 *	5/2017	Lee	H01L 51/001
2010/0289728 A1	11/2010	Nakatani et al.	

(Continued)

FOREIGN PATENT DOCUMENTS

JP	2005-251497 A	9/2005
KR	10-2009-0028513 A	3/2009

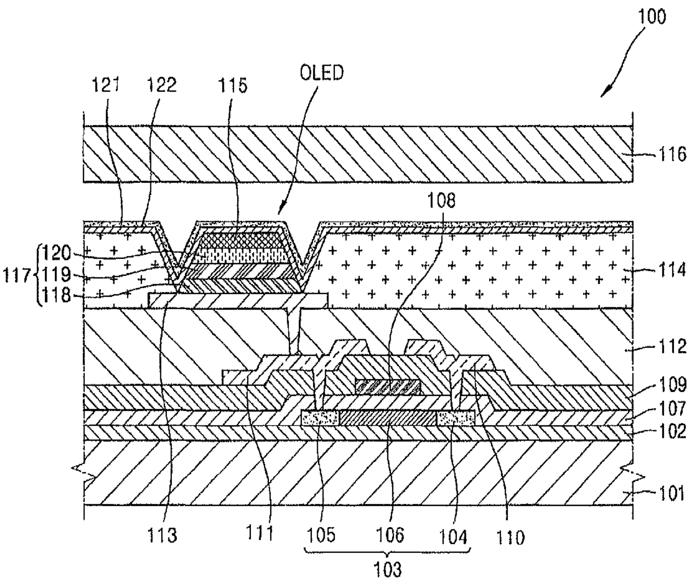
(Continued)

Primary Examiner — Kyoung Lee
(74) *Attorney, Agent, or Firm* — Lee & Morse, P.C.

(57) **ABSTRACT**

Provided are an organic light-emitting display apparatus and a method of manufacturing the same. The organic light-emitting display apparatus includes a display substrate; a thin film transistor (TFT) on the display substrate; an organic light-emitting diode (OLED) electrically connected to the TFT and including a first electrode on sub-pixels of the display substrate, an intermediate layer on the first electrode, and a second electrode on the intermediate layer; a pixel-defining layer which includes an opening exposing at least a portion of the first electrode and defines each sub-pixel; and a sealing substrate covering the OLED, the intermediate layer including a plurality of stacked layers, and a cross-sectional width of the intermediate layer gradually decreasing in a direction perpendicular to the display substrate.

15 Claims, 7 Drawing Sheets



(51) **Int. Cl.**
H01L 51/56 (2006.01)
H01L 51/52 (2006.01)
H01L 51/00 (2006.01)

(52) **U.S. Cl.**
CPC ***H01L 51/5012*** (2013.01); ***H01L 51/5056*** (2013.01); ***H01L 51/5072*** (2013.01); ***H01L 51/5088*** (2013.01); ***H01L 51/5092*** (2013.01); ***H01L 51/524*** (2013.01); ***H01L 51/5228*** (2013.01); ***H01L 51/5253*** (2013.01); ***H01L 51/56*** (2013.01); *H01L 51/5268* (2013.01); *H01L 2227/323* (2013.01); *H01L 2251/55* (2013.01)

(58) **Field of Classification Search**
CPC H01L 2227/323; H01L 51/5088; H01L 51/5072; H01L 51/5056; H01L 51/5268; H01L 51/5092; H01L 51/56
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2011/0084291	A1	4/2011	Jeong et al.
2012/0181554	A1	7/2012	Irving et al.
2013/0236999	A1	9/2013	Lee et al.

FOREIGN PATENT DOCUMENTS

KR	10-2010-0051106	A	5/2010
KR	10-2012-0076940	A	7/2012
WO	WO 2011/139771	A2	11/2011

* cited by examiner

FIG. 1

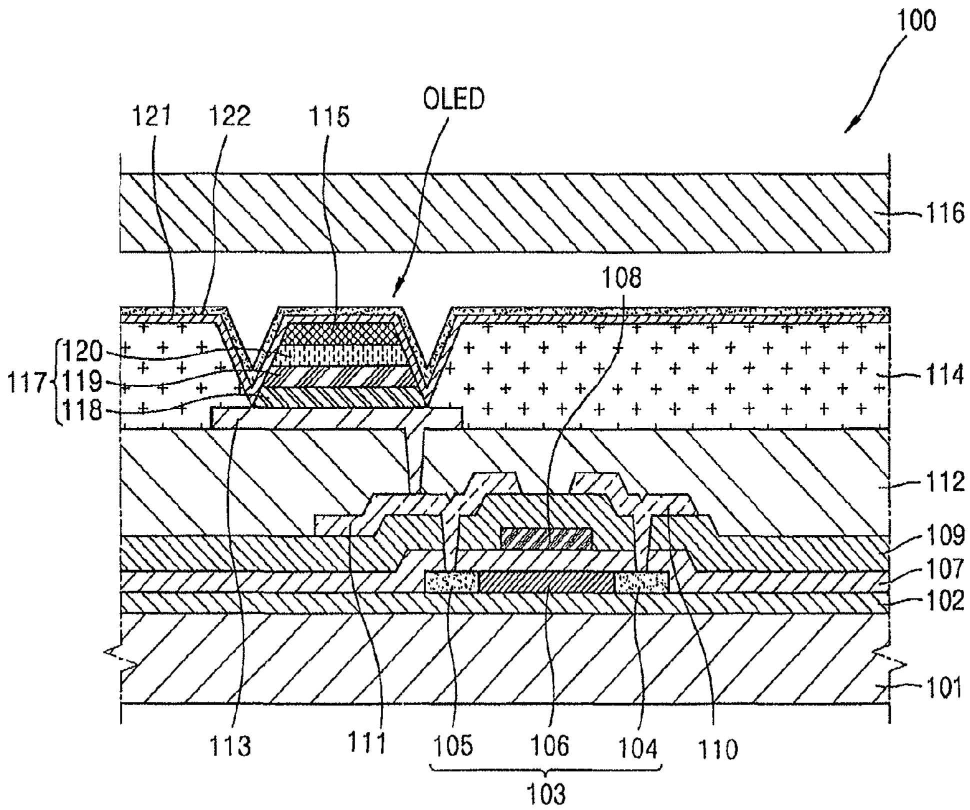

100
121
122
115
OLED
116
108
120
117
119
118
114
112
109
107
102
101
113
111
105
106
104
110
103

FIG. 2A

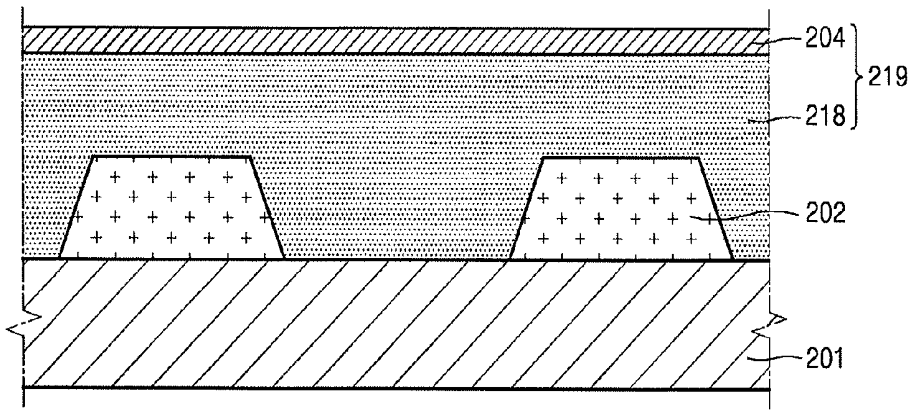


FIG. 2B

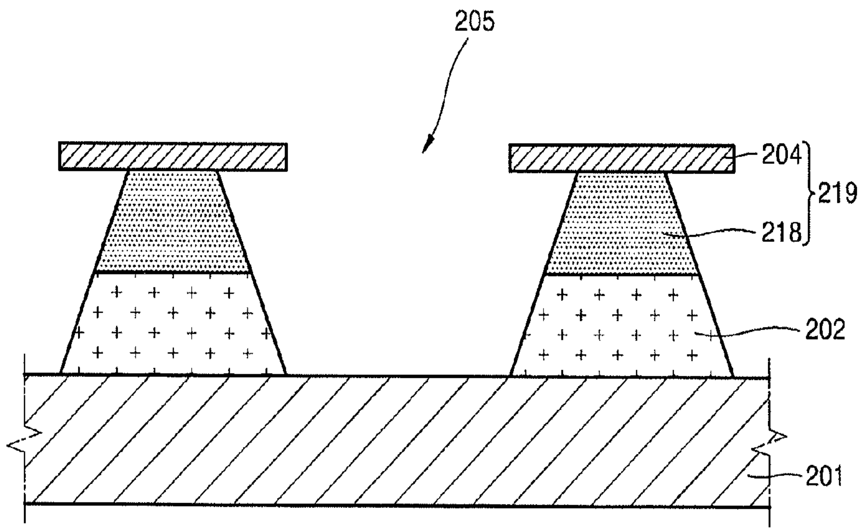


FIG. 2C

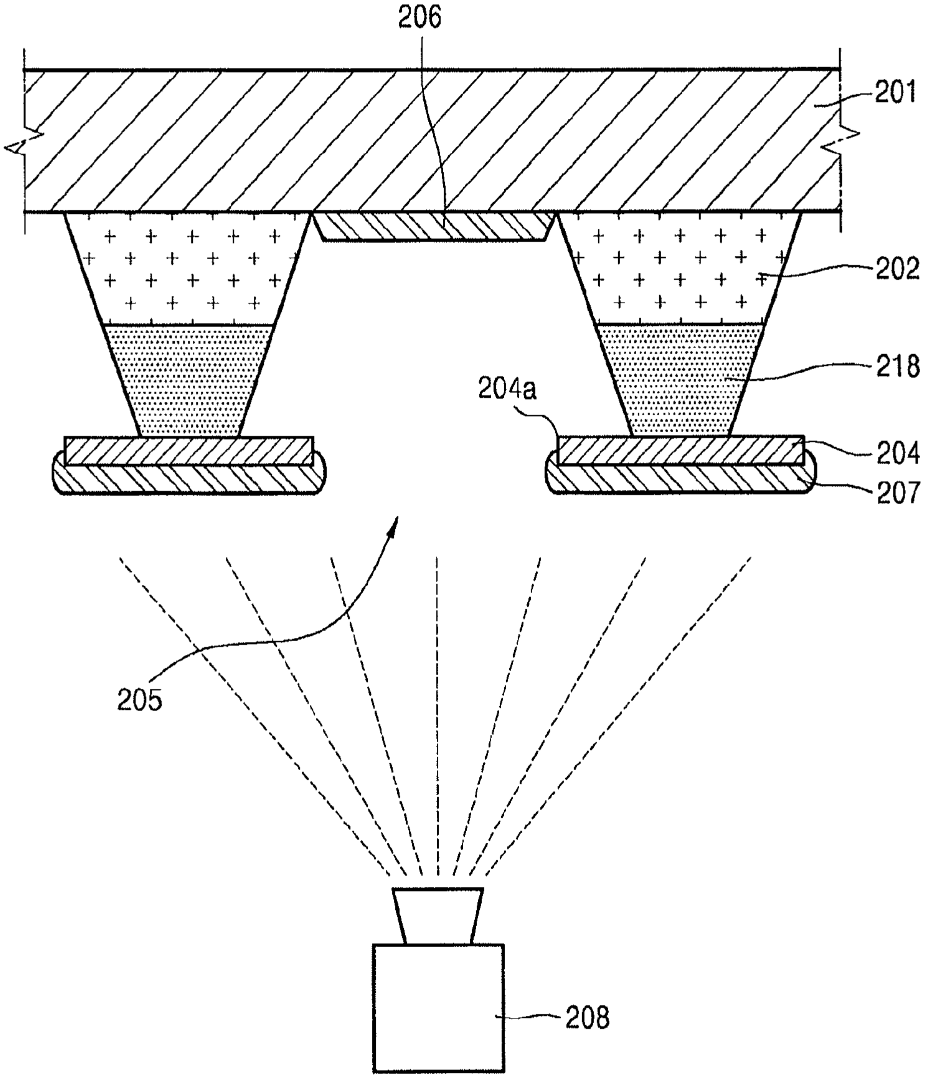


FIG. 2D

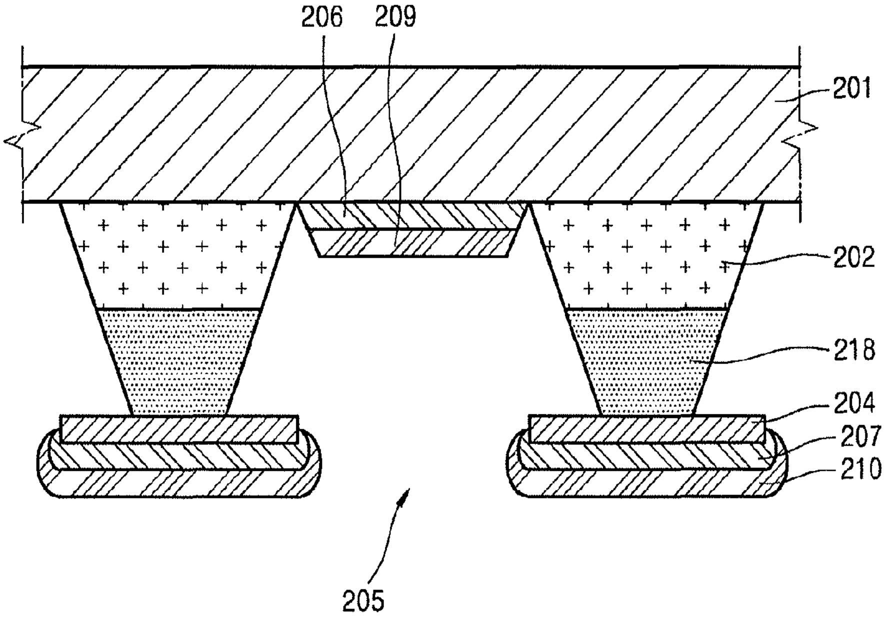

206
209
201
202
218
204
207
210
205

FIG. 2E

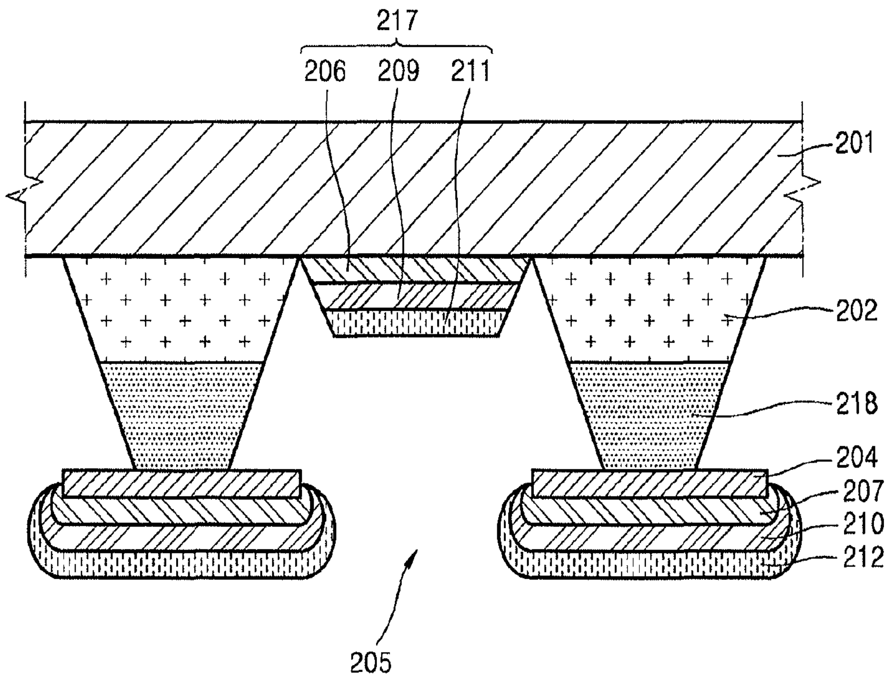

217
206
209
211
201
202
218
204
207
210
212
205

FIG. 2F

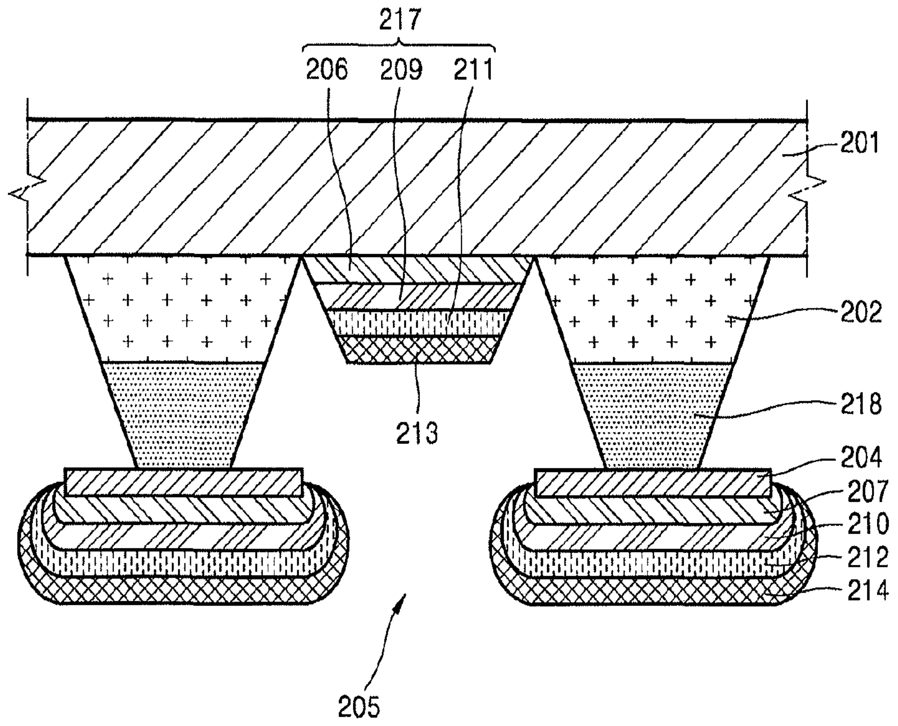

217
206
209
211
201
202
218
213
204
207
210
212
214
205

FIG. 2G

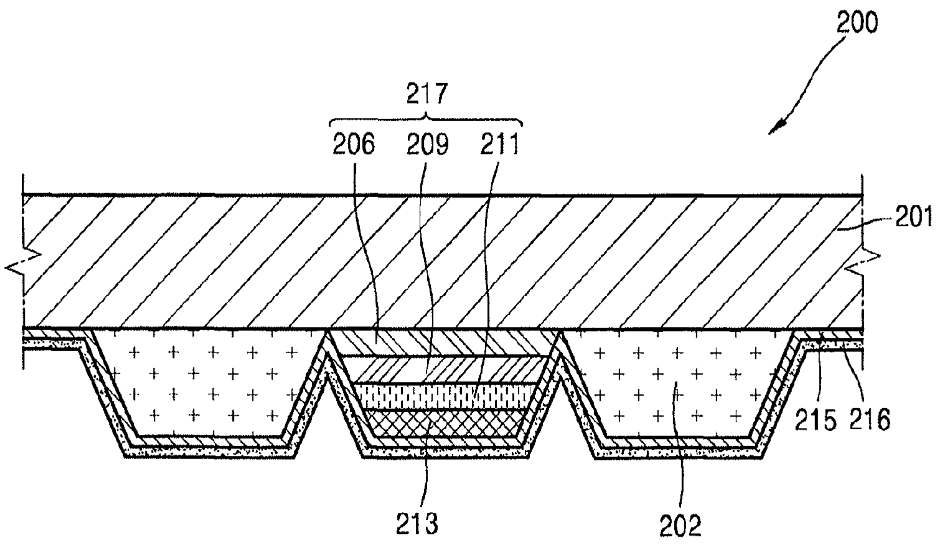

200
217
206
209
211
201
215
216
213
202

FIG. 3A

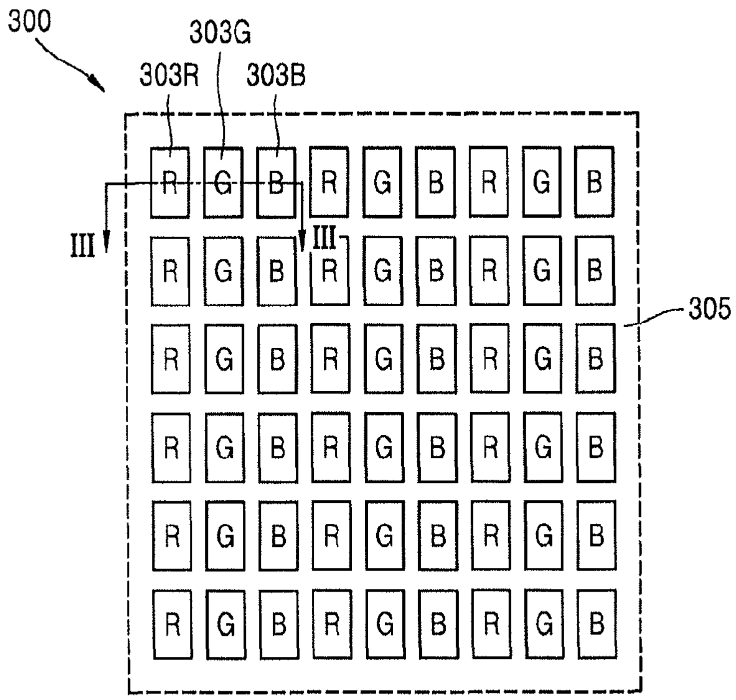

300
303G
303R
303B
III
III
305
R G B R G B R G B

FIG. 3B

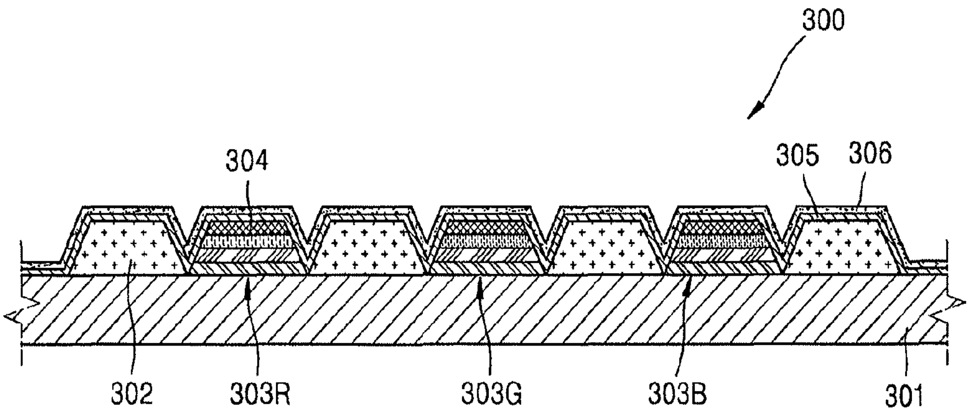
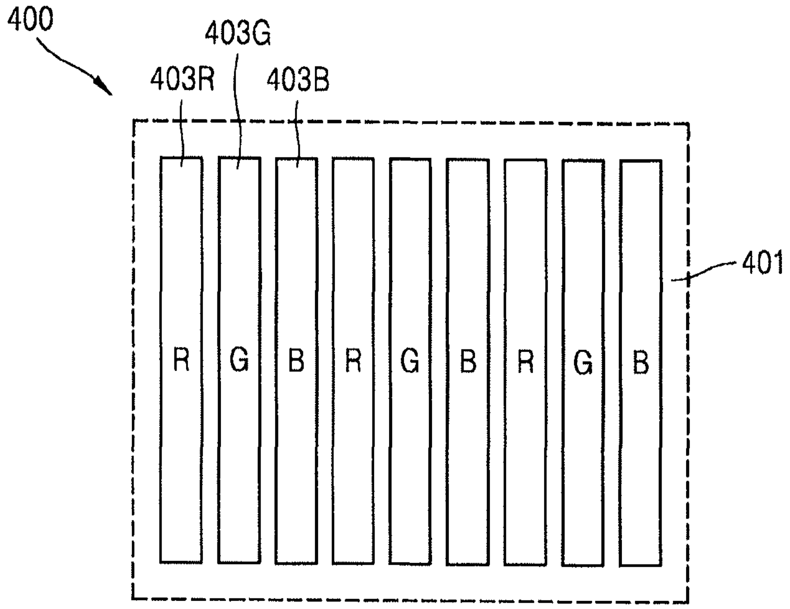

300
304
305
306
302
303R
303G
303B
301

FIG. 4



ORGANIC LIGHT-EMITTING DISPLAY APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

This is a continuation application based on pending application Ser. No. 14/797,295, filed Jul. 13, 2015, the entire contents of which is hereby incorporated by reference.

Korean Patent Application No. 10-2014-0143593, filed on Oct. 22, 2014, in the Korean Intellectual Property Office, and entitled: "Organic Light-Emitting Display Apparatus and Fabrication Method Thereof," is incorporated by reference herein in its entirety.

BACKGROUND

1. Field

One or more exemplary embodiments relate to an organic light-emitting display apparatus and a method of manufacturing the same.

2. Description of the Related Art

An organic light-emitting display apparatus may be used for a mobile device such as a smart phone, a tablet personal computer (PC), a laptop, a digital camera, a camcorder, or a personal digital assistant (PDA), or an electronic device such as an ultra-thin television or electronic billboard.

SUMMARY

Embodiments may be realized by providing an organic light-emitting display apparatus, including a display substrate; a thin film transistor (TFT) on the display substrate; an organic light-emitting diode (OLED) electrically connected to the TFT and including a first electrode on sub-pixels of the display substrate, an intermediate layer on the first electrode, and a second electrode on the intermediate layer; a pixel-defining layer which includes an opening exposing at least a portion of the first electrode and defines each sub-pixel; and a sealing substrate covering the OLED, the intermediate layer including a plurality of stacked layers, and a cross-sectional width of the intermediate layer gradually decreasing in a direction perpendicular to the display substrate.

The perpendicular direction may be a direction between the sealing substrate and the display substrate, and the cross-sectional width of the intermediate layer may gradually decrease from the display substrate toward the sealing substrate.

The intermediate layer may be positive-taper shaped.

An angle of a taper of the intermediate layer may be an acute angle.

The intermediate layer may include an emissive layer; and at least one pattern layer stacked on at least one surface of the emissive layer.

The at least one pattern layer may include one or more of a hole injection layer (HIL), a hole transport layer (HTL), an electron transport layer (ETL), or an electron injection layer (EIL).

A first pattern layer including the HIL and the HTL may be between the first electrode and the emissive layer, a second pattern layer including the ETL and the EIL may be between the emissive layer and the second electrode, and a cross-sectional width of the first pattern layer may be larger than a cross-sectional width of the second pattern layer.

The intermediate layer may only be in an emission area of each sub-pixel defined by the pixel-defining layer.

The second electrode may be in a portion of the emission area of each sub-pixel, the portion corresponding to the intermediate layer, and n auxiliary electrode may be electrically connected to the second electrode and may be on the emission area of each sub-pixel and the pixel-defining layer in order to apply a common voltage to each sub-pixel.

The second electrode may be on the emission area of each sub-pixel and the pixel-defining layer.

An area of a cross-section of at least one layer of the stacked layers may be smaller than an area of a cross-section at least another layer of the stacked layers, the at least one layer being above the at least another layer in a direction from the display substrate to the sealing substrate.

Embodiments may be realized by providing method of manufacturing an organic light-emitting display apparatus, the method including forming a pixel-defining layer, which includes an opening exposing at least a portion of a first electrode of an organic light-emitting diode (OLED) and defining sub-pixels, on a display substrate; patterning a photo-pattern layer on the display substrate; forming an intermediate layer of the OLED on the first electrode through the opening; forming a second electrode of the OLED on the intermediate layer; and removing the photo-pattern layer from the display substrate, forming the intermediate layer including stacking a plurality of layers, the plurality of layers having cross-sectional widths gradually decreasing in size in a direction perpendicular to the display substrate.

The method may further include forming a resin covering the pixel-defining layer, and forming a photoresist on the resin. Patterning the photo-pattern layer may include light-exposing, developing, and etching the resin and the photoresist so as to expose the opening.

The plurality of layers of the intermediate layer may be formed after deposition materials are emitted from a deposition source toward the opening and the deposition materials are deposited on the display substrate, a portion of which is exposed to the outside by the opening, and a plurality of deposition layers formed of the same deposition materials as in the plurality of layers may be formed on the photo-pattern layer, which is formed on the pixel-defining layer while the intermediate layer is formed.

The method may further include forming a sealing substrate which covers the OLED. The plurality of deposition layers on the photo-pattern layer may gradually cover the opening during continuous deposition, and a cross-sectional width of the intermediate layer on the display substrate may gradually decrease in size from the display substrate to the sealing substrate.

The intermediate layer may be positive-taper shaped.

An angle of a taper of the intermediate layer may be an acute angle, and the intermediate layer may include at least one pattern layer stacked on at least one surface of an emissive layer, and the emissive layer and the at least one pattern layer may be sequentially deposited in a direction perpendicular to the display substrate.

The at least one pattern layer may include one or more of a hole injection layer (HIL), a hole transport layer (HTL), an electron transport layer (ETL), or an electron injection layer (EIL).

The second electrode may be formed on the intermediate layer in an emission area of each sub-pixel, and after the photo-pattern layer is removed, an auxiliary electrode electrically connected to the second electrode may be forming on the emission area of each sub-pixel and the pixel-defining layer.

The intermediate layer may only be formed on an emission area of each sub-pixel defined by the pixel-defining layer.

BRIEF DESCRIPTION OF THE DRAWINGS

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

FIG. **1** illustrates a cross-sectional view of a sub-pixel of an organic light-emitting display apparatus, according to an exemplary embodiment;

FIGS. **2**A through **2**G sequentially illustrate a method of forming a thin film on a display substrate, according to an exemplary embodiment;

FIG. **3**A illustrates a plan view of an organic light-emitting diode (OLED) of an organic light-emitting display apparatus, according to an exemplary embodiment;

FIG. **3**B illustrates a cross-sectional view taken along a line of FIG. **3**A; and

FIG. **4** illustrates a plan view of an OLED of an organic light-emitting display apparatus, according to another exemplary embodiment.

DETAILED DESCRIPTION

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

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

While such terms as "first", "second", etc., may be used to describe various components, such components must not be limited to the above terms. The above terms are used only to distinguish one component from another.

The terms used in the present specification are merely used to describe particular embodiments, and are not intended to be limiting. An expression used in the singular encompasses the expression of the plural, unless it has a clearly different meaning in the context. In the present specification, it is to be understood that the terms such as "including", "having", and "comprising" are intended to indicate the existence of the features, numbers, steps, actions, components, parts, or combinations thereof disclosed in the specification, and are not intended to preclude the possibility that one or more other features, numbers, steps, actions, components, parts, or combinations thereof may exist or may be added.

One or more embodiments of an organic light-emitting display apparatus and a method of manufacturing the same will be described with reference to the accompanying drawings. Like reference numerals in the drawings denote like elements, and their description will be omitted.

FIG. **1** illustrates a cross-sectional view of a sub-pixel of an organic light-emitting display apparatus **100**, according to an exemplary embodiment. Referring to FIG. **1**, the organic light-emitting display apparatus **100** may include a display substrate **101** and a sealing substrate **116** facing the display substrate **101**.

The display substrate **101** may be formed of insulating materials having flexibility or rigidity. For example, the display substrate **101** may be a flexible film, a glass substrate having rigidity, a metal substrate, or a combination thereof. The display substrate **101** may be transparent, translucent, or opaque.

A barrier layer **102** may be formed on the display substrate **101**. The barrier layer **102** may cover an entire upper surface of the display substrate **101**.

The barrier layer **102** may include an inorganic layer or an organic layer. For example, the barrier layer **102** may be formed of one or more of inorganic materials such as silicon oxide (SiO_x), silicon nitride (SiN_x), silicon oxynitride (SiON), aluminum oxide (AlO), and aluminum oxynitride (AlON), or organic materials such as acryl, polyimide, and polyester.

The barrier layer **102** may be a single layer or multiple layers. The barrier layer **102** may prevent penetration of oxygen and moisture and may flatten the upper surface of the display substrate **101**.

A thin film transistor (TFT) may be formed on the barrier layer **102**. In the present exemplary embodiment, the TFT is a top gate transistor, but may be another type of transistor, for example, a bottom gate transistor.

A semiconductor active layer **103** may be formed on the barrier layer **102**. The semiconductor active layer **103** may include a source area **104** and a drain area **105** doped with N-type impurity ions or P-type impurity ions. A channel area **106** which is not doped with impurities may be disposed between the source area **104** and the drain area **105**.

The semiconductor active layer **103** may be an inorganic semiconductor formed of amorphous silicon, or poly silicon or an organic semiconductor.

The semiconductor active layer **103** may be an oxide semiconductor. For example, the oxide semiconductor may include oxides of Group 4, 12, 13 and 14 elements such as zinc (Zn), indium (In), gallium (Ga), tin (Sn), cadmium (Cd), germanium (Ge), and hafnium (Hf), and combinations thereof.

A gate insulating layer **107** may be deposited on the semiconductor active layer **103**. The gate insulating layer **107** may be an inorganic layer formed of SiO_x, SiN_X, or a metal oxide. The gate insulating layer **107** may be a single layer or multiple layers.

A gate electrode **108** may be formed on the gate insulating layer **107**. The gate electrode **108** may have a single layer or multiple layers formed of, for example, Au, Ag, Cu, Ni, Pt, Pd, Al, Mo, or Cr. The gate electrode **108** may include an alloy such as Al:Nd or Mo:W.

An interlayer insulating layer **109** may be formed on the gate electrode **108**. The interlayer insulating layer **109** may be an inorganic layer formed of, for example, SiOx or SiNx. The interlayer insulating layer **109** may be an organic layer.

A source electrode **110** and a drain electrode **111** may be formed on the interlayer insulating layer **109**. For example, contact holes may be formed in the gate insulating layer **107** and the interlayer insulating layer **109** by selectively removing portions of the gate insulating layer **107** and the interlayer insulating layer **109**. Through the contact holes, the source electrode **110** may be electrically connected to the source area **104**, and the drain electrode **111** may be electrically connected to the drain area **105**.

A protective layer **112** (a passivation layer and/or planarization layer) may be formed on the source electrode **110** and the drain electrode **111**. The protective layer **112** may cover the source electrode **110** and the drain electrode **111**. The protective layer **112** may include an inorganic material such as SiO_x or SiN_x, or an organic material such as acryl, polyimide, or benzocyclobutene (BCB).

An organic light-emitting diode (OLED) may be formed on the TFT.

The OLED may be formed on the protective layer **112**. The OLED may include a first electrode **113**, an intermediate layer **117**, and a second electrode **115**.

The first electrode **113** may be electrically connected to the source electrode **110** or the drain electrode **111** through the contact holes formed by removing portions of the protective layer **112**.

The first electrode **113** may function as an anode and may be formed of various conductive materials. The first electrode **113** may include a transparent electrode or a reflective electrode. For example, when the first electrode **113** is used as a transparent electrode, the first electrode **113** may include a transparent conductive layer formed of, for example, indium tin oxide (ITO), indium zinc oxide (IZO), zinc oxide (ZnO), or indium oxide (In_2O_3). When the first electrode **113** is used as a reflective electrode, the first electrode **113** may form a reflective layer by using Ag, Mg, Al, Pt, Pd, Au, Ni, Nd, Ir, Cr, or a combination thereof, and a transparent conductive layer formed of, for example, ITO, IZO, ZnO, or In_2O_3, may be formed on an upper surface of the reflective layer.

A pixel-defining layer **114** may be formed on the protective layer **112** and may cover a portion of the first electrode **113**. The pixel-defining layer **114** may define an emission area of each sub-pixel by surrounding edges of the first electrode **113**. The first electrode **113** may be patterned on each sub-pixel.

The pixel-defining layer **114** may be an organic or inorganic layer. For example, the pixel-defining layer **114** may be formed of organic materials such as, for example, polyimide, polyamide, BCB, acrylic resin, or phenol resin, or inorganic materials such as SiN_x.

The pixel-defining layer **114** may be a single layer or multiple layers.

The intermediate layer **117** may be formed on an area of the first electrode **113** which is exposed by etching a portion of the pixel-defining layer **114**. The intermediate layer **117** may be formed by deposition.

The intermediate layer **117** may have a multilayer structure.

For example, the intermediate layer **117** may include an emissive layer **119** and at least one pattern layer **118** and **120** formed on at least one surface of the emissive layer **119**. The at least one pattern layer **118** and **120** may be formed in a direction perpendicular to the display substrate **101**.

The intermediate layer **117** may include the emissive layer **119** and may further include one or more of a hole injection layer (HIL), a hole transport layer (HTL), an electron transport layer (ETL), or an electron injection layer (EIL). In an embodiment, the intermediate layer **117** may include the emissive layer **119** and may further include various functional layers such as a scattering layer.

In the present exemplary embodiment, a first pattern layer **118** may be formed between the first electrode **113** and the emissive layer **119**. The first pattern layer **118** may include an HIL and an HTL. A second pattern layer **120** may be formed between the emissive layer **119** and the second electrode **115**. The second pattern layer **120** may include an ETL and an EIL.

Holes and electrons injected from the first electrode **113** and the second electrode **115** may be combined in the emissive layer **119** and may emit light of desired colors.

The second electrode **115** may be formed on the intermediate layer **117**.

The second electrode **115** may function as a cathode. The second electrode **115** may include a transparent electrode or a reflective electrode. For example, when the second electrode **115** is used as a transparent electrode, metals having a low work function, for example, lithium (Li), calcium (Ca), lithium fluoride (LiF)/Ca, LiF/Al, Al, magnesium (Mg), or a combination thereof may be deposited on the intermediate layer **117**, and the transparent conductive layer formed of ITO, IZO, ZnO, In_2O_3, etc. may be formed on the above metals or combination. When the second electrode **115** is used as a reflective electrode, the second electrode **115** may be formed of Li, Ca, LiF/Ca, LiF/Al, Al, Mg, and/or a combination thereof.

In the present exemplary embodiment, the first electrode **113** may function as an anode, and the second electrode **115** may function as a cathode. In an embodiment, the first electrode **113** may function as a cathode, and the second electrode **115** may function as an anode.

In an embodiment, multiple sub-pixels may be formed on the display substrate **101**, and each of the sub-pixels may emit red light, green light, blue light, or white light.

The intermediate layer **117** may be formed to substantially cover the first electrode **113** regardless of locations of the sub-pixels. In an emissive layer, layers including emissive materials which respectively emit red light, green light, and blue light may be vertically stacked, or the emissive layer may be formed of mixtures of the emissive materials which respectively emit red light, green light, and blue light.

If an emissive material emits white light, it may be possible to mix other colors. The emissive layer may further include a color-converting layer or a color filter which converts the emitted white color into light of another color.

The sealing substrate **116** may be formed on the OLED. The sealing substrate **116** may be formed to protect the intermediate layer **117** and other thin films from, for example, moisture or oxygen, penetrating from the outside.

The sealing substrate **116** may be glass having rigidity or a film having polymer resin or flexibility. The sealing substrate **116** may have a structure in which organic layers and inorganic layers are alternately stacked on the OLED.

In the present exemplary embodiment, the intermediate layer **117** may have a stack structure in which multiple layers are stacked. Areas of respective cross-sections of the stacked layers may gradually decrease in the direction perpendicular to the display substrate **101**.

The intermediate layer **117** may include the first pattern layer **118** including the HIL and HTL, the emissive layer **119**, and the second pattern layer **120** including the ETL and the EIL.

The layers included in the intermediate layer **117** may continue to be stacked in an upward direction from an upper surface of the display substrate **101**. A cross-section of the intermediate layer **117** may gradually decrease in size, e.g., in width in a direction perpendicular to the upward direction from the upper surface of the display substrate, from the display substrate **101** to the sealing substrate **116**. For example, a cross-sectional width of a bottom layer of the intermediate layer **117**, that is, a cross-sectional width of the first pattern layer **118**, may be larger than a cross-sectional width of a top layer of the intermediate layer **117**, that is, a cross-sectional width of the second pattern layer **120**. The cross-sectional width of the bottom layer of the intermediate layer **117**, that is, the cross-sectional width of the first pattern layer **118**, may be larger than a cross-sectional width of the emissive layer **119**. The cross-sectional width of the emissive layer **119** may be larger than the cross-sectional width of the top layer of the intermediate layer **117**, that is, the cross-sectional width of the second pattern layer **120**. In an embodiment, a cross-sectional width of the first pattern layer **118** may be the largest, and that of the second pattern layer may be the smallest **120**.

FIG. **1** illustrates an area of a cross-section of the intermediate layer taken in a transverse plane that extends in a perpendicular direction relative to the display substrate decreasing in a direction perpendicular to the display substrate.

The intermediate layer **117** may be positive-taper shaped, and an angle of the intermediate layer **117** may be acute. For example, an angle between the bottom layer of the intermediate layer **117** which contacts the first electrode **113** and a side surface of the intermediate layer **117** may be smaller than 90 degrees.

The intermediate layer **117** may be deposited through a deposition process. The intermediate layer **117** may be formed only in an emission area of each sub-pixel defined by the pixel-defining layer **114**.

In the present exemplary embodiment, emissive materials having different colors may be respectively deposited in the sub-pixels, and the sub-pixels may respectively emit red light, green light, and blue light. In another exemplary embodiment, emissive materials having red, green, and blue colors may be vertically stacked, and the emissive materials having red, green, and blue colors may be mixed in one sub-pixel.

The first pattern layer **118** including the HIL and the HTL may be commonly formed. In the present exemplary embodiment, each of the HIL and the HTL may be formed in the emission area of each sub-pixel. The first pattern layer **118** may not be formed on an outer surface of the pixel-defining layer **114**.

The second pattern layer **120** including the ETL and the EIL may also be commonly formed. As in the case of the first pattern layer **118**, the second pattern layer **120** may be formed in the emission area of each sub-pixel.

The second electrode **115** may be formed on an upper surface of the second pattern layer **120**. The second electrode **115** may be formed on each sub-pixel. The second electrode **115** may be an electrode which applies a common voltage to each sub-pixel.

An auxiliary electrode **121** may be further formed to apply the common voltage to each sub-pixel. The auxiliary electrode **121** may be electrically connected to the second electrode **115**. The auxiliary electrode **121** may be formed on the emission area of each pixel and the pixel-defining layer **114**. In the present exemplary embodiment, the auxiliary electrode **121** may be formed on an outer surface of the pixel-defining layer **114**, an outer surface of the second electrode **115**, and side surfaces of the intermediate layer **117**.

In the present exemplary embodiment, the second electrode **115** used as a common electrode and the auxiliary electrode **121** may be respectively formed. If the second electrode **115** applies the common voltage to every sub-pixel, a structure of the second electrode **115** may not be a single structure. For example, without the auxiliary electrode **121**, the second electrode **115** may be formed on the emission area of each sub-pixel and the pixel-defining layer **114**.

A capping layer **122** for protecting the OLED may be further formed on the auxiliary electrode **121**.

FIGS. **2**A through **2**G sequentially illustrate a method of forming a thin film on a display substrate **201**, according to an exemplary embodiment. At least one TFT and a first electrode of the OLED may be formed on the display substrate **201**, and illustrations and descriptions thereof will be omitted. Referring to FIG. **2**A, pixel-defining layers **202** which define sub-pixels may be formed on the display substrate **201**. A photo-pattern layer **219** may be formed on the pixel-defining layers **202**.

Resin **218** which may completely cover the pixel-defining layers **202** may be formed on the display substrate **201**. A photoresist **204** may be formed on the resin **218**. The resin **218** and the photoresist **204** may be formed by spin coating, etc.

As shown in FIG. **2**B, the photo-pattern layer **219** may be patterned by exposing the photoresist **204** to light and developing the same and by etching the resin **218**. An opening **205** which exposes at least a portion of the first electrode **113** (refer to FIG. **1**) may be formed between the pixel-defining layers **202** which are adjacent to each other. The opening **205** may correspond to the emission area of each sub-pixel.

As shown in FIG. **2**C, a first pattern layer **206** may be formed on the display substrate **201**.

To this end, the display substrate **201** may be arranged on an upper portion of a chamber and a deposition source **208** may be arranged on a lower portion of the chamber. Then, a predetermined amount of heat is provided to the deposition source **208**, and deposition materials may be applied by vapor deposition to the display substrate **201** from the deposition source **208**. The first pattern layer **206**, the emissive layer **209**, and a second pattern layer **211** to be described later may be formed by continuous deposition.

The first pattern layer **206** may be formed on the first electrode **113** (refer to FIG. **1**). The first pattern layer **206** may include an HIL and an HTL. The first pattern layer **206** may be deposited on the display substrate **201** through the opening **205**.

A cross-section of the first pattern layer **206** may gradually decrease in size in a direction away from the display substrate **201**, for example, due to an undercut in a lower portion **204***a* of the photoresist **204**.

While the first pattern layer **206** is formed, a first deposition layer **207** may be formed on the photoresist **204** by using the same materials as in the first pattern layer **206**.

As shown in FIG. **2**D, the emissive layer **209** may be formed on the display substrate **201**. The emissive layer **209** may include materials emitting red, green, and blue light and may form a deposition material corresponding to one of red, green, and blue colors.

The emissive layer **209** may be formed on the first pattern layer **206**. While the emissive layer **209** is formed, a second deposition layer **210** may be formed on the first deposition layer **207** by using the same materials as in the emissive layer **209**.

Since the first deposition layer **207** may be deposited on the photoresist **204** and the second deposition layer **210** may be deposited on the first deposition layer **207**, thicknesses of layers, for example, thicknesses of the photoresist **204**, the first deposition layer **207**, and the second deposition layer **210**, may gradually increase.

In proportion to the increase of the thicknesses of the layers **204**, **207** and **210**, the opening **205** via which the deposition materials pass may be gradually covered. An entrance of the opening **205** may become smaller than an entrance of an initial opening **205**, and an amount of the deposition materials passing the opening **205** may be decreased, and a cross-section, e.g., cross-sectional width, of the emissive layer **209** may be smaller than that of the first pattern layer **206** in the direction perpendicular to the display substrate **201**.

As shown in FIG. **2**E, the second pattern layer **211** may be formed on the display substrate **201**. The second pattern layer **211** may include an ETL and an EIL.

The second pattern layer **211** may be formed on the emissive layer **209**. A cross-section e.g., cross-sectional width, of the second pattern layer **211** may be smaller than that of the emissive layer **209** in the direction perpendicular to the display substrate **201**. While the second pattern layer **211** is formed, a third deposition layer **212** may be formed on the second deposition layer **210** by using the same material as in the second pattern layer **211**.

An intermediate layer **217** including the first pattern layer **206**, the emissive layer **209**, and the second pattern layer **211** may be formed on the emission area of a sub-pixel defined by the pixel-defining layers **202**, and a cross-section of the intermediate layer **217** may gradually decrease in size in the direction perpendicular to the display substrate **201**.

A profile angle of the intermediate layer **217** may be acute.

The profile angle may be arbitrarily adjusted by adjusting a deposition incidence angle while the deposition materials are vaporized by using the deposition source **208** (refer to FIG. **2**C) or changing thicknesses of the resin **218** and the photoresist **204** coated on the display substrate **201**. For example, the deposition incidence angle of the deposition materials may be increased or the thicknesses of the resin **218** and the photoresist **204** may be decreased to increase the profile angle.

As shown in FIG. **2**F, a second electrode **213** may be formed on the display substrate **201**. The second electrode **213** may be formed by deposition.

The second electrode **213** may be formed on the second pattern layer **211**. While the second electrode **213** is formed, a fourth deposition layer **214** may be formed on the third deposition layer **212** by using the same material as in the second electrode **213**. A cross-section e.g., cross-sectional width, of the second electrode **213** may be smaller than that of the second pattern layer **211** in the direction perpendicular to the display substrate **201**.

Then, the resin **218**, the photoresist **204**, the first deposition layer **207**, the second deposition layer **210**, the third deposition layer **212**, and the fourth deposition layer **214** respectively formed on the pixel-defining layers **202** may be removed. For example, a lift-off process in which the resin **218** is separated from the pixel-defining layers **202** may be performed to remove the resin **218**, the photoresist **204**, the first deposition layer **207**, the second deposition layer **210**, the third deposition layer **212**, and the fourth deposition layer **214** by injecting a solution reacting to the resin **218**.

The intermediate layer **217** and the second electrode **213** may be formed only on the emission area of the sub-pixel defined by the pixel-defining layers **202**.

In the present exemplary embodiment, the second electrode **213** may be formed on the emission area of the sub-pixel through the opening **205** and may function as a common electrode which applies a common voltage to every sub-pixel.

As shown in FIG. **2**G, an auxiliary electrode **215** which may be electrically connected to the second electrode **213** may be formed on the display substrate **201**. The auxiliary electrode **215** may be formed on the emission area of each sub-pixel and the pixel-defining layers **202**. In the present exemplary embodiment, the auxiliary electrode **215** may be formed on outer surfaces of the pixel-defining layers **202**, an outer surface of the second electrode **213**, and side surfaces of the intermediate layer **217**.

The second electrode **213** formed on the emission area of each sub-pixel and the auxiliary electrode **215** formed on an entire area of the display substrate **201** may be electrically connected to each other and may be used as common electrodes which apply the common voltage to every sub-pixel.

Without the auxiliary electrode **215**, the second electrode **213** may be formed on the emission area of each sub-pixel and the outer surfaces of the pixel-defining layers **202**, instead of being formed only on the emission area of each sub-pixel.

A capping layer **216** may be further formed on the auxiliary electrode **215**, and may protect the OLED.

FIG. **3**A illustrates a plan view of an OLED of an organic light-emitting display apparatus **300**, according to an exemplary embodiment, and FIG. **3**B illustrates a cross-sectional view taken along a line of FIG. **3**A. Referring to FIGS. **3**A and **3**B, a red intermediate layer **303**R, a green intermediate layer **303**G, and a blue intermediate layer **303**B may be arranged on a display substrate **301**. The red intermediate layer **303**R, the green intermediate layer **303**G, and the blue intermediate layer **303**B may be formed on an emission area of each sub-pixel defined by a pixel-defining layer **302**. The red intermediate layer **303**R, the green intermediate layer **303**G, and the blue intermediate layer **303**B may have a dot pattern.

A second electrode **304** may be formed on the red intermediate layer **303**R, the green intermediate layer **303**G, and the blue intermediate layer **303**B. The second electrode **304** may be formed on the emission area of each sub-pixel.

An auxiliary electrode **305** may be formed on the second electrode **304**. The auxiliary electrode **305** may be formed on an outer surface of the pixel-defining layer **302**, an outer surface of the second electrode **304**, and side surfaces of the red intermediate layer **303**R, the green intermediate layer **303**G, and the blue intermediate layer **303**B. The second electrode **304** and the auxiliary electrode **305** may be electrically connected to each other.

FIG. **4** illustrates a plan view of an OLED of an organic light-emitting display apparatus **400**, according to another exemplary embodiment. Referring to FIG. **4**, a red intermediate layer **403**R, a green intermediate layer **403**G, and a blue intermediate layer **403**B may be arranged on a display substrate **401**. The red intermediate layer **403**R, the green intermediate layer **403**G, and the blue intermediate layer **403**B may be formed on an emission area of each sub-pixel.

The red intermediate layer **403**R, the green intermediate layer **403**G, and the blue intermediate layer **403**B may have a stripe pattern. The red intermediate layer **403**R, the green intermediate layer **403**G, and the blue intermediate layer **403**B have the same cross-section pattern as the red intermediate layer **303**R, the green intermediate layer **303**G, and the blue intermediate layer **303**B of FIG. **3**, and descriptions thereof will be omitted.

By way of summation and review, an organic light-emitting display apparatus may have an emissive layer disposed between an anode and a cathode. The anode, the cathode, and the emissive layer may be formed by photolithography or deposition.

As described above, according to the one or more of the above exemplary embodiments of the organic light-emitting display apparatus and the method of manufacturing the same, pattern profiles of, for example, the common electrode or the capping layer, may be gradually formed on the intermediate layer. Short circuiting of wires may be prevented, and a high-resolution and large-sized organic light-emitting display apparatus may be provided.

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

What is claimed is:

1. An organic light-emitting display apparatus comprising:

a display substrate;

an organic light-emitting diode (OLED) including a first electrode, an intermediate layer on the first electrode, and a second electrode on the intermediate layer; and

a pixel-defining layer including an opening that exposes at least a portion of the first electrode,

wherein the intermediate layer includes a plurality of layers, and

areas of upper surfaces of the plurality of layers decrease in a direction perpendicular to the display substrate, the direction being a direction away from the display substrate.

2. The organic light-emitting display apparatus of claim **1**, wherein an area of an upper surface of a bottom layer of the intermediate layer is the greatest, the bottom layer being the closest to the display substrate, and

an area of an upper surface of a top layer of the intermediate layer is the smallest, the top layer being the farthest from the display substrate.

3. The organic light-emitting display apparatus of claim **2**, wherein the plurality of layers of the intermediate layer continue to be stacked in the direction away from the display substrate.

4. The organic light-emitting display apparatus of claim **2**, wherein, when viewed from a top view, the upper surface of the top layer of the intermediate layer is within the upper surface of the bottom layer of the intermediate layer.

5. The organic light-emitting display apparatus of claim **1**, wherein the intermediate layer includes:

an emissive layer; and

at least one pattern layer stacked on at least one surface of the emissive layer.

6. The organic light-emitting display apparatus of claim **5**, wherein the at least one pattern layer includes at least one of a hole injection layer (HIL), a hole transport layer (HTL), an electron transport layer (ETL), or an electron injection layer (EIL).

7. The organic light-emitting display apparatus of claim **6**, wherein a first pattern layer including the HIL and the HTL is between the first electrode and the emissive layer,

a second pattern layer including the ETL and the EIL is between the emissive layer and the second electrode, and

an area of an upper surface of the first pattern layer is greater than an area of an upper surface of the second pattern layer.

8. The organic light-emitting display apparatus of claim **5**, wherein the intermediate layer is in an emission area of each of sub-pixels defined by the pixel-defining layer.

9. The organic light-emitting display apparatus of claim **5**, wherein the second electrode is in the emission area of each sub-pixel,

an auxiliary electrode is on the second electrode and is electrically connected to the second electrode in order to apply a common voltage to each sub-pixel, and

the auxiliary electrode extends over the emission area of each sub-pixel and the pixel-defining layer.

10. The organic light-emitting display apparatus of claim **5**, wherein the second electrode extends over the emission area of each sub-pixel and the pixel-defining layer.

11. The organic light-emitting display apparatus of claim **1**, wherein a cross-sectional width of the intermediate layer decreases in the direction perpendicular to the display substrate.

12. The organic light-emitting display apparatus of claim **11**, wherein the intermediate layer is positive-taper shaped.

13. The organic light-emitting display apparatus of claim **12**, wherein an angle of a taper of the intermediate layer is an acute angle.

14. The organic light-emitting display apparatus of claim **11**, wherein each of the plurality of layers of the intermediate layer has a cross-sectional width decreasing in the direction away from the display substrate.

15. The organic light-emitting display apparatus of claim **11**, wherein a cross-sectional area of at least one layer of the plurality of layers is smaller than a cross-sectional area of at least another layer of the plurality of layers, and

the at least one layer is above the at least another layer in the direction away from the display substrate.

* * * * *

专利名称(译)	有机发光显示装置		
公开(公告)号	US9954040	公开(公告)日	2018-04-24
申请号	US15/490665	申请日	2017-04-18
[标]申请(专利权)人(译)	三星显示有限公司		
申请(专利权)人(译)	三星DISPLAY CO.，LTD.		
当前申请(专利权)人(译)	三星DISPLAY CO.，LTD.		
[标]发明人	LEE DUCKJUNG KANG TAEWOOK KIM JAESIK		
发明人	LEE, DUCKJUNG KANG, TAEWOOK KIM, JAESIK		
IPC分类号	H01L27/32 H01L51/50 H01L51/56 H01L51/52 H01L51/00		
CPC分类号	H01L27/3246 H01L51/001 H01L51/5012 H01L51/5056 H01L51/5072 H01L51/5088 H01L51/5092 H01L51/524 H01L51/5228 H01L51/5253 H01L51/56 H01L27/3211 H01L2251/55 H01L51/5268 H01L2227/323		
审查员(译)	LEE，KYOUNG		
优先权	1020140143593 2014-10-22 KR		
其他公开文献	US20170221973A1		
外部链接	Espacenet USPTO		

摘要(译)

提供一种有机发光显示装置及其制造方法。有机发光显示装置包括显示基板;显示基板上的薄膜晶体管（TFT）;有机发光二极管（OLED），与TFT电连接，包括显示基板的子像素上的第一电极，第一电极上的中间层和中间层上的第二电极;像素限定层，包括暴露第一电极的至少一部分并限定每个子像素的开口;覆盖OLED的密封基板，中间层包括多个堆叠层，中间层的横截面宽度在垂直于显示基板的方向上逐渐减小。