US007294962B2

(12) United States Patent
Kim et al.

(10) Patent No.: US 7,294,962 B2

(45) Date of Patent: Nov. 13, 2007

(54) **ORGANIC ELECTROLUMINESCENT DISPLAY DEVICE AND METHOD FOR MANUFACTURING THE SAME**

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(73) Assignee: **Samsung SDI Co., Ltd.**, Suwon (KR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 204 days.

(21) Appl. No.: **10/937,294**

(22) Filed: **Sep. 10, 2004**

(65) **Prior Publication Data**

US 2005/0116623 A1 Jun. 2, 2005

(30) **Foreign Application Priority Data**

Nov. 29, 2003 (KR) 10-2003-0086154

(51) **Int. Cl.**
H05B 33/00 (2006.01)

(52) **U.S. Cl.** **313/504**; 445/23

(58) **Field of Classification Search** 313/501-506
See application file for complete search history.

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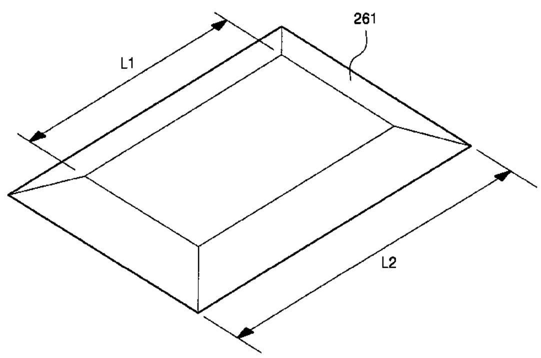
(57) **ABSTRACT**

The invention is directed to an improved organic electroluminescent device. In one embodiment, the OLED includes a thin film transistor formed in a non-emission region on an insulating substrate that also includes source and drain electrodes. The OLED further includes a lower electrode formed in an emission region on the insulating substrate and connected to one electrode of the source/drain electrodes through a contact hole. The OLED yet further includes an organic emission layer formed in the emission region on the lower electrode, and an upper electrode formed on the organic emission layer, wherein the lower electrode has a surface with its corners rounded off. The lower electrode acts as a pixel electrode. Having its surface with corners rounded off prevents short-induced defects caused by outgassing.

10 Claims, 14 Drawing Sheets



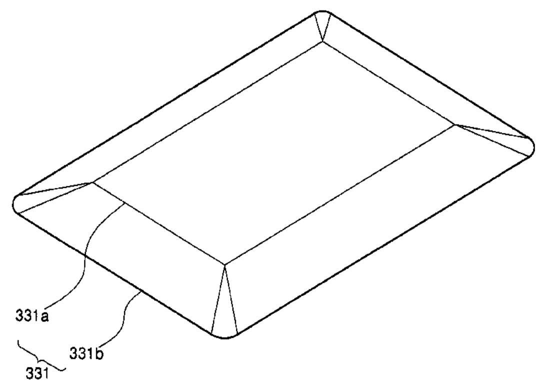


FIG. 1A

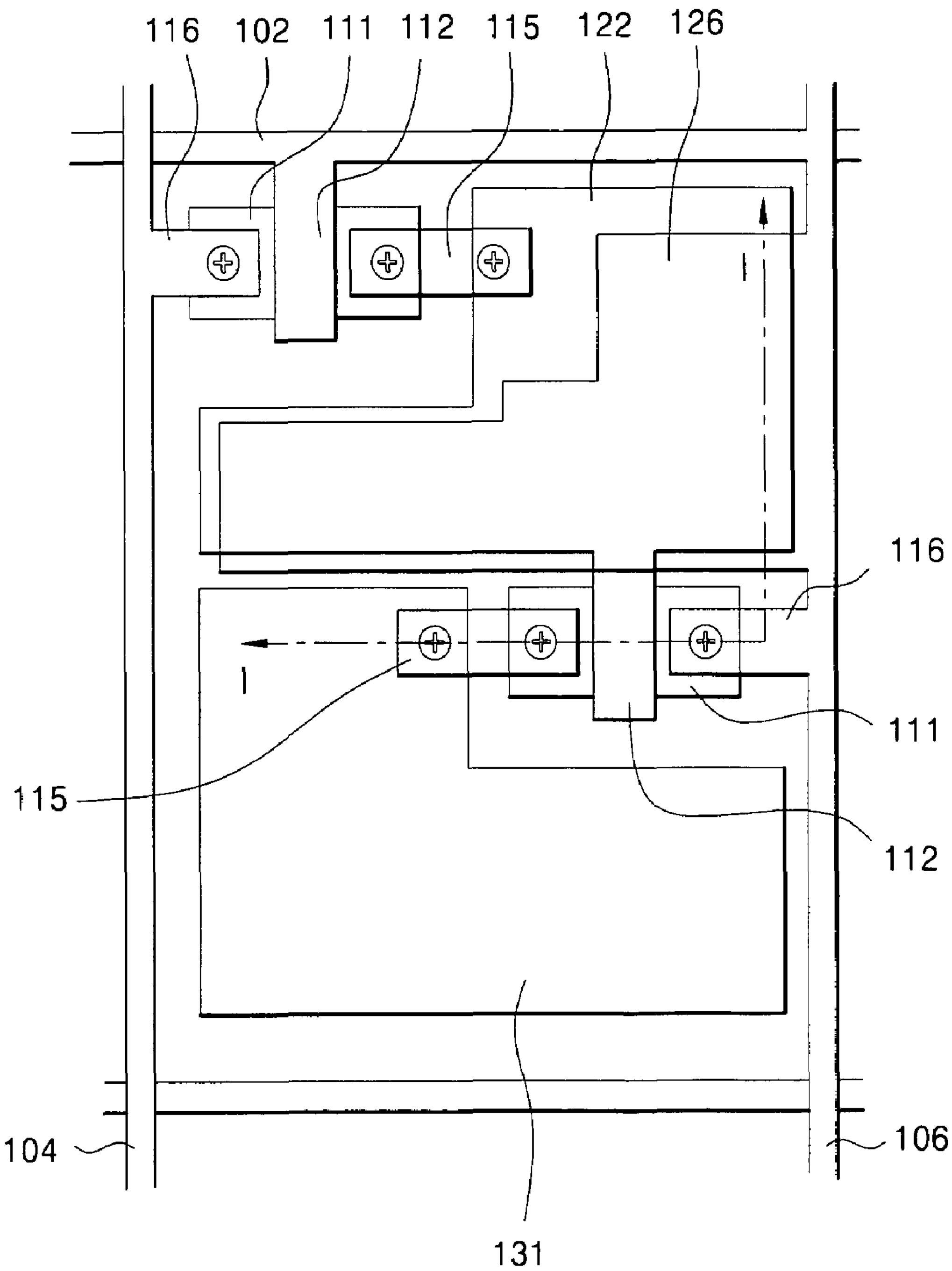
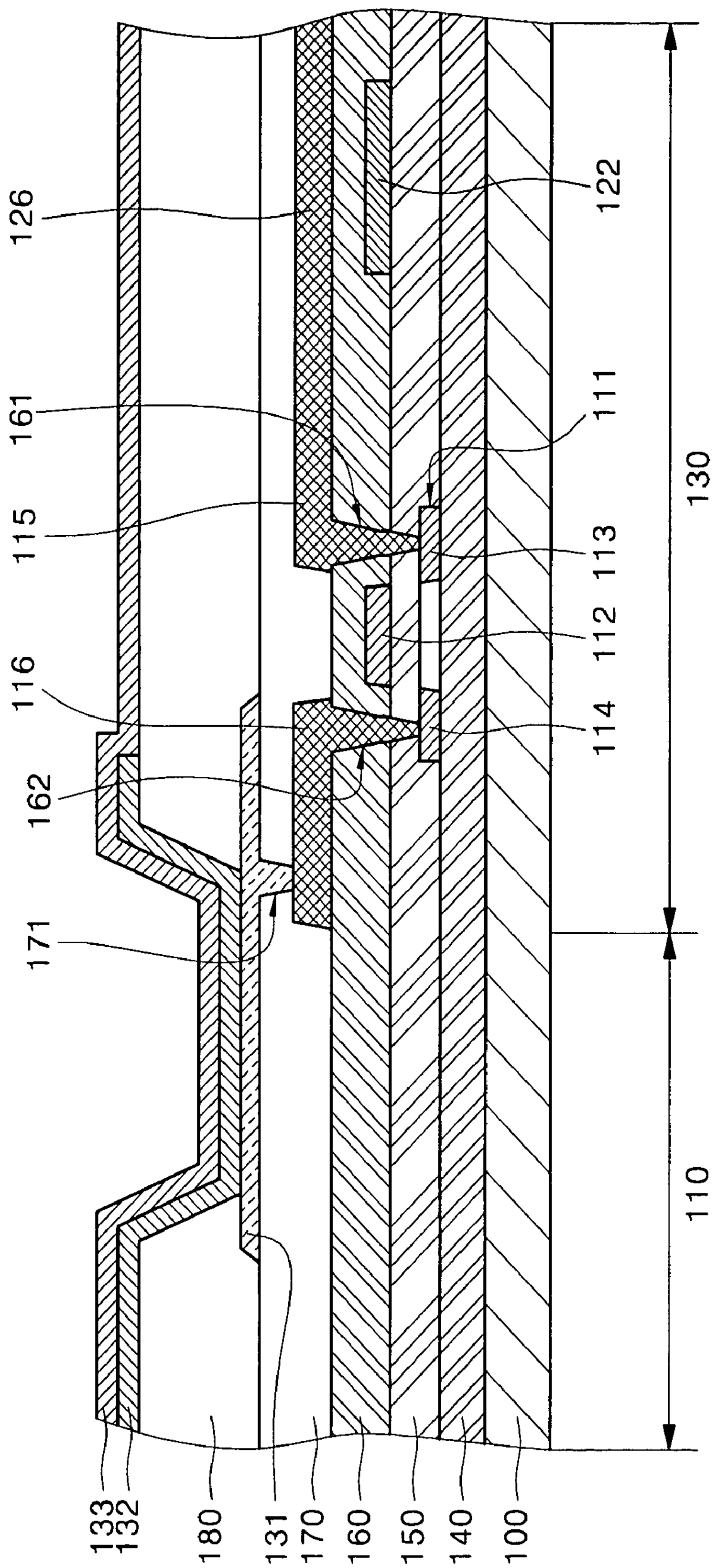


FIG. 1B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122
161
111
130
115
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171
110
133
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180
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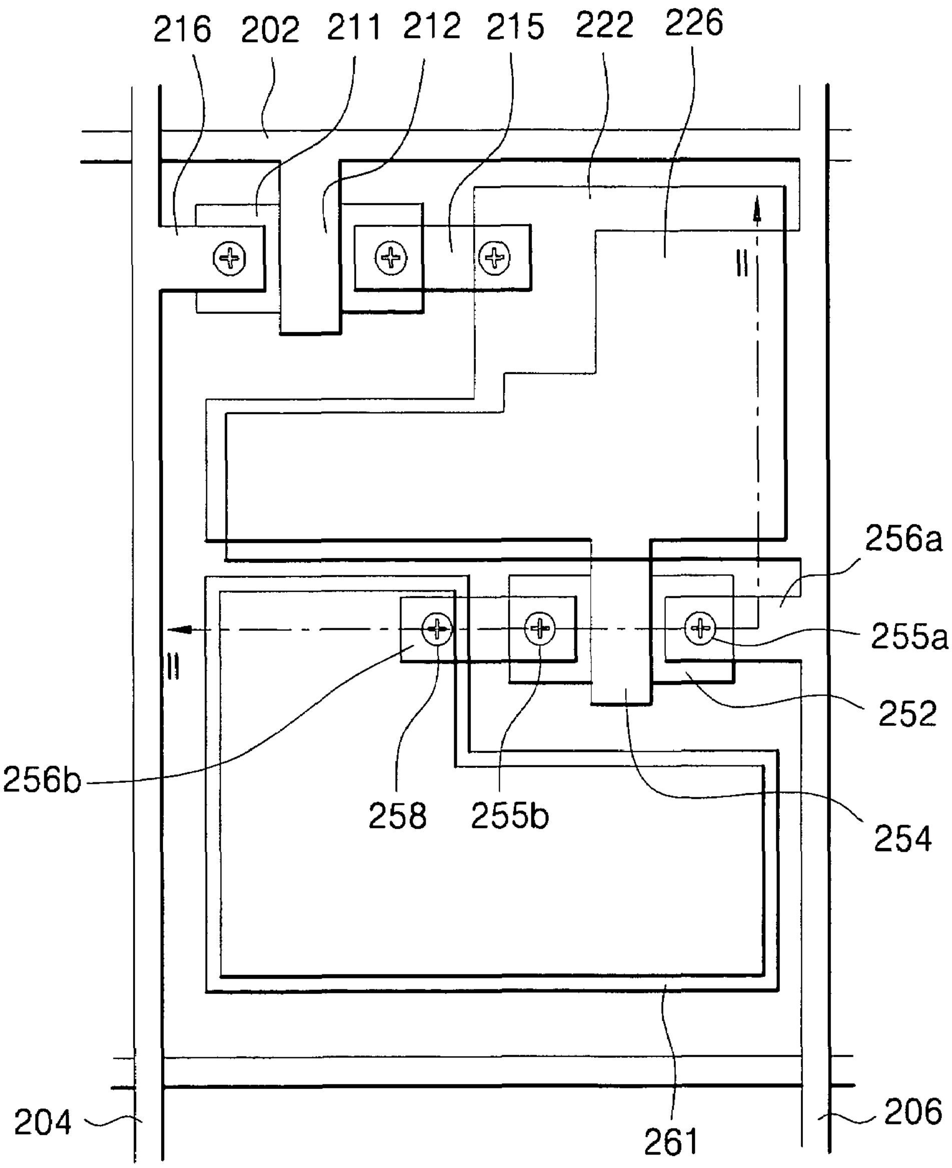
160
150
140
100

FIG. 2A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202
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255a
252
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256b
258
255b
II
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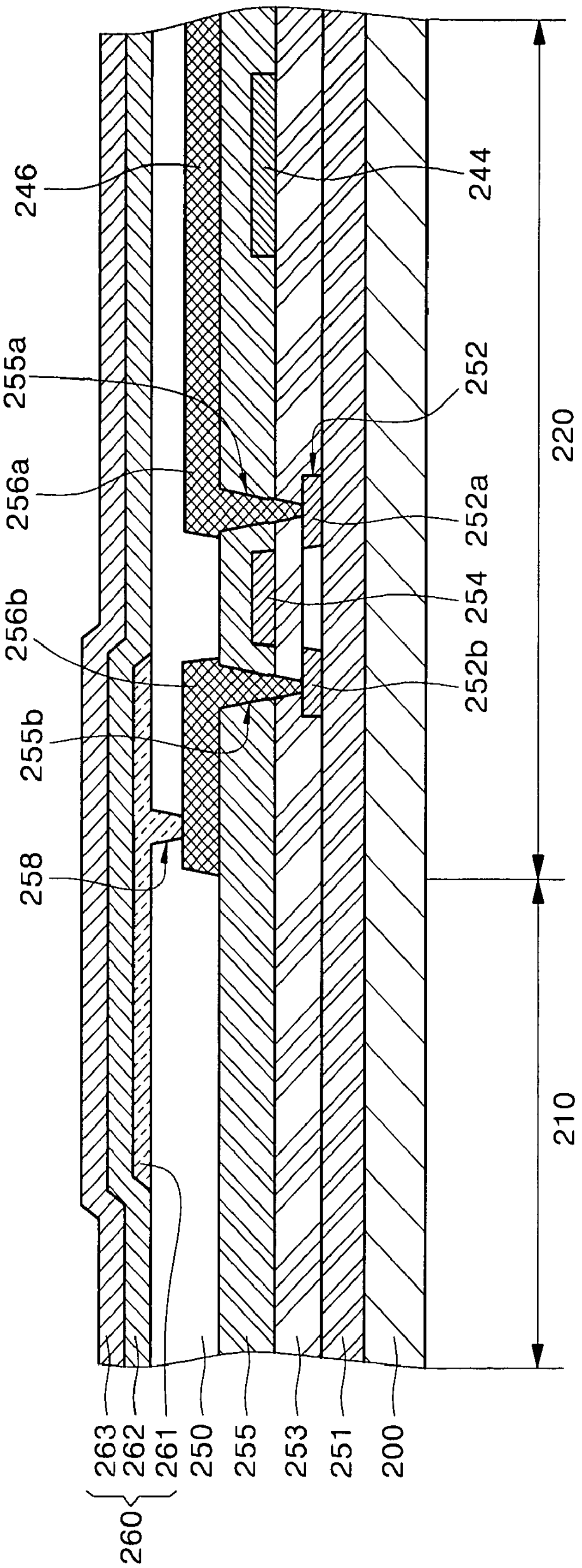
261
206

FIG. 2B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244
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252
256a
220
252a
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256b
252b
255b
258
210
263
262
261
250
255
253
251
200
260

FIG. 2C

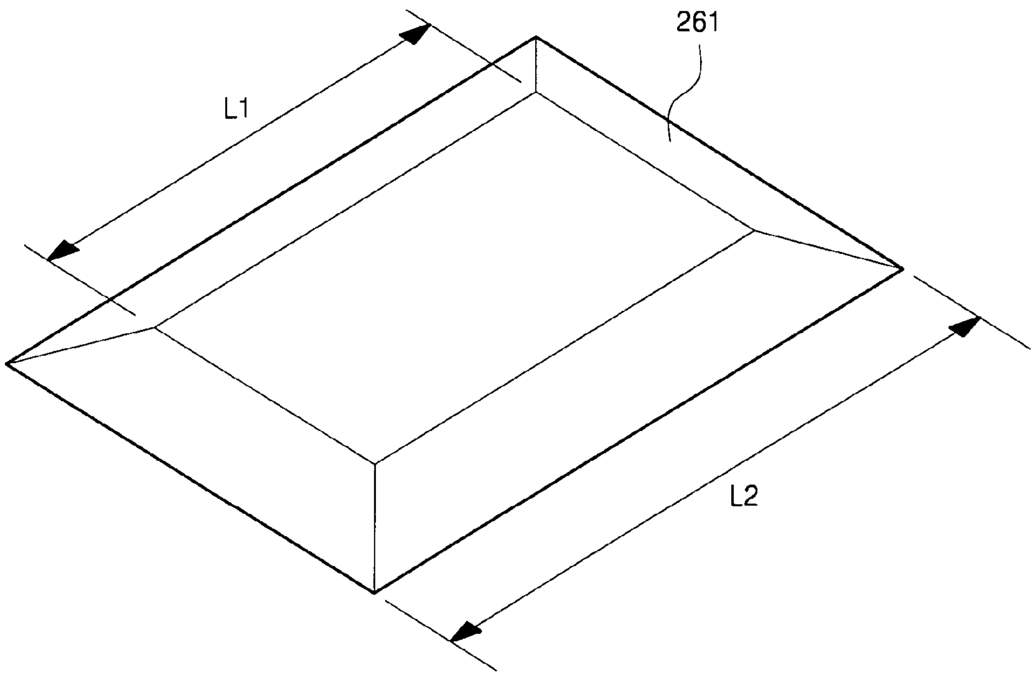


FIG. 2D

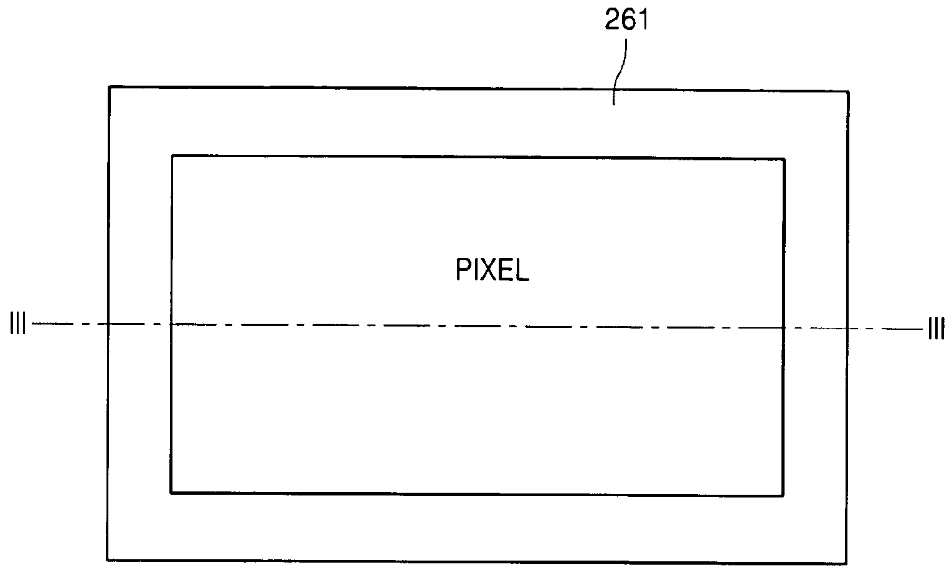


FIG. 2E

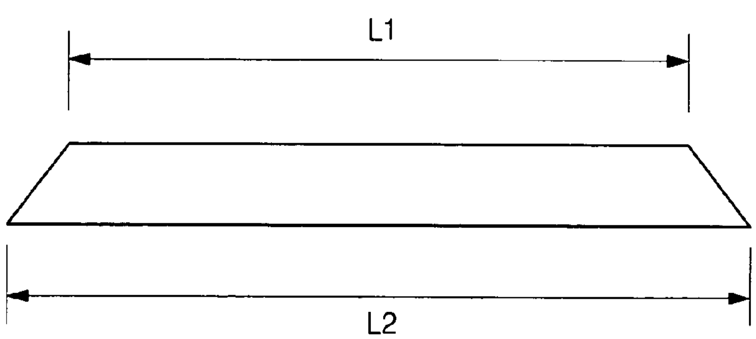


FIG. 2F

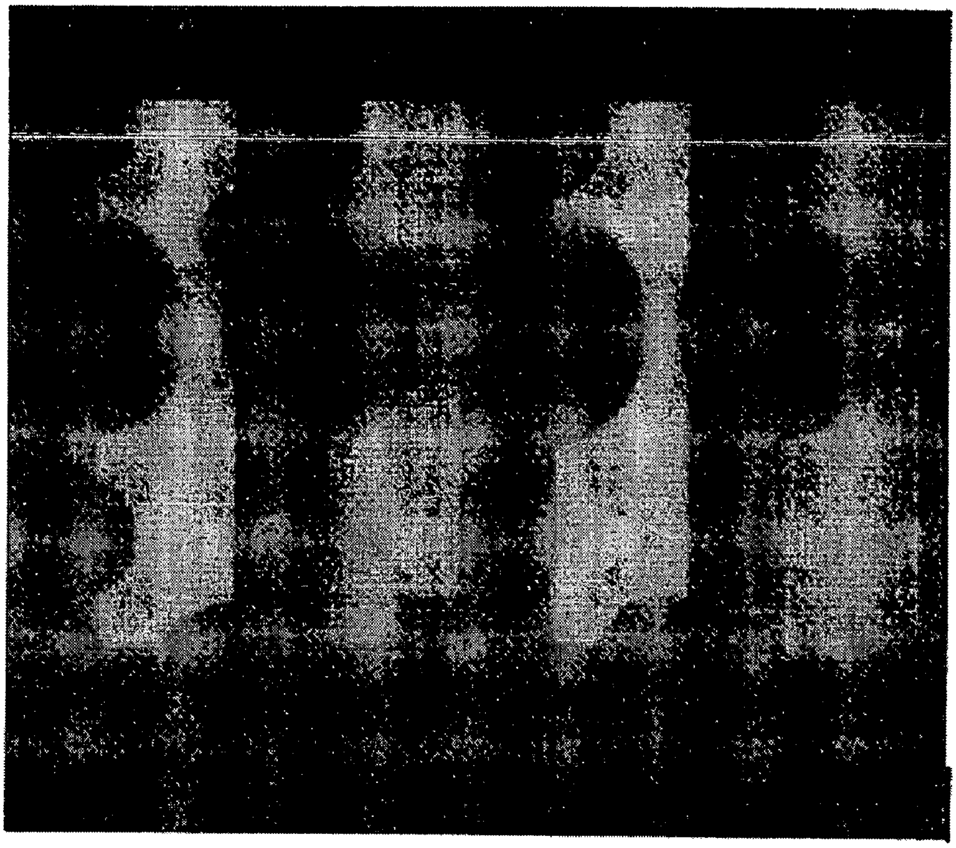
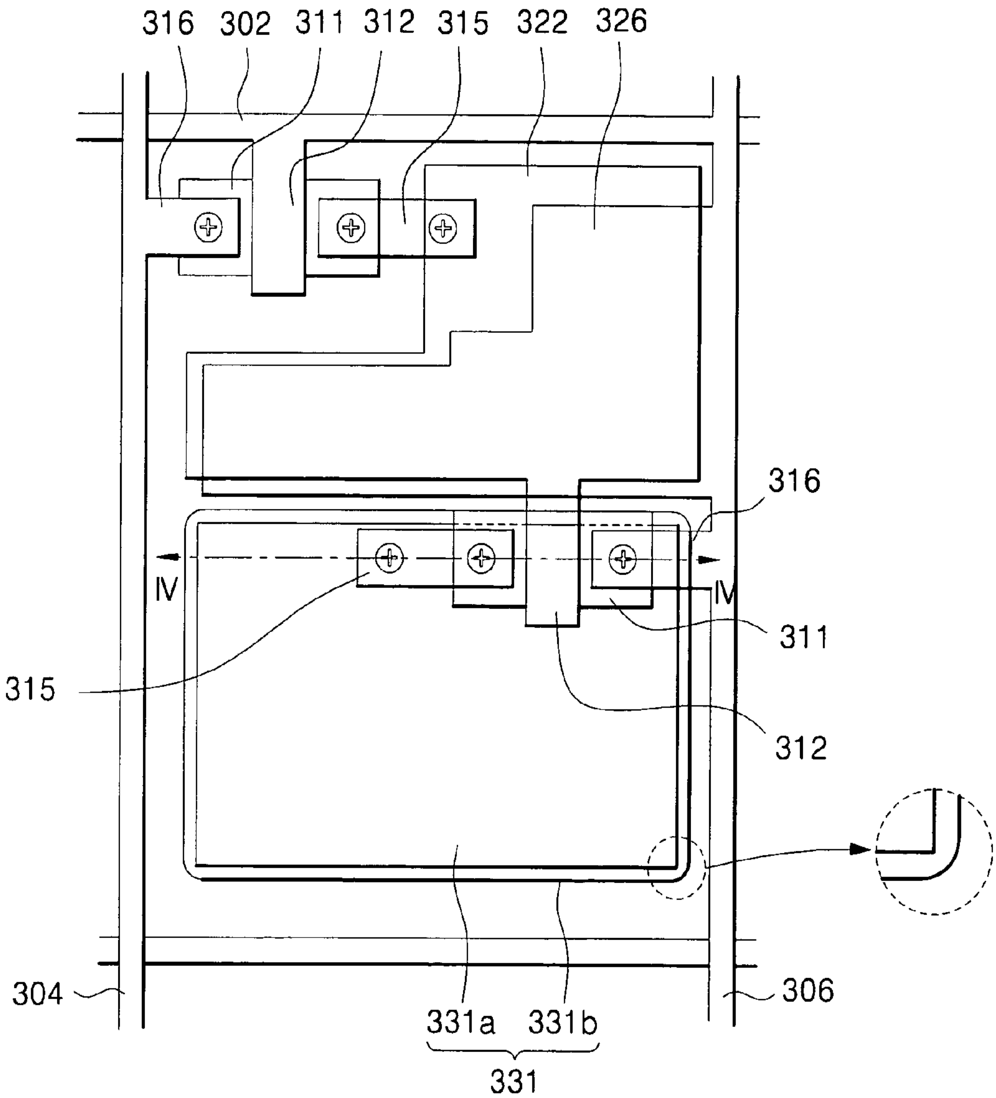


FIG. 3A


316
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312
315
322
326
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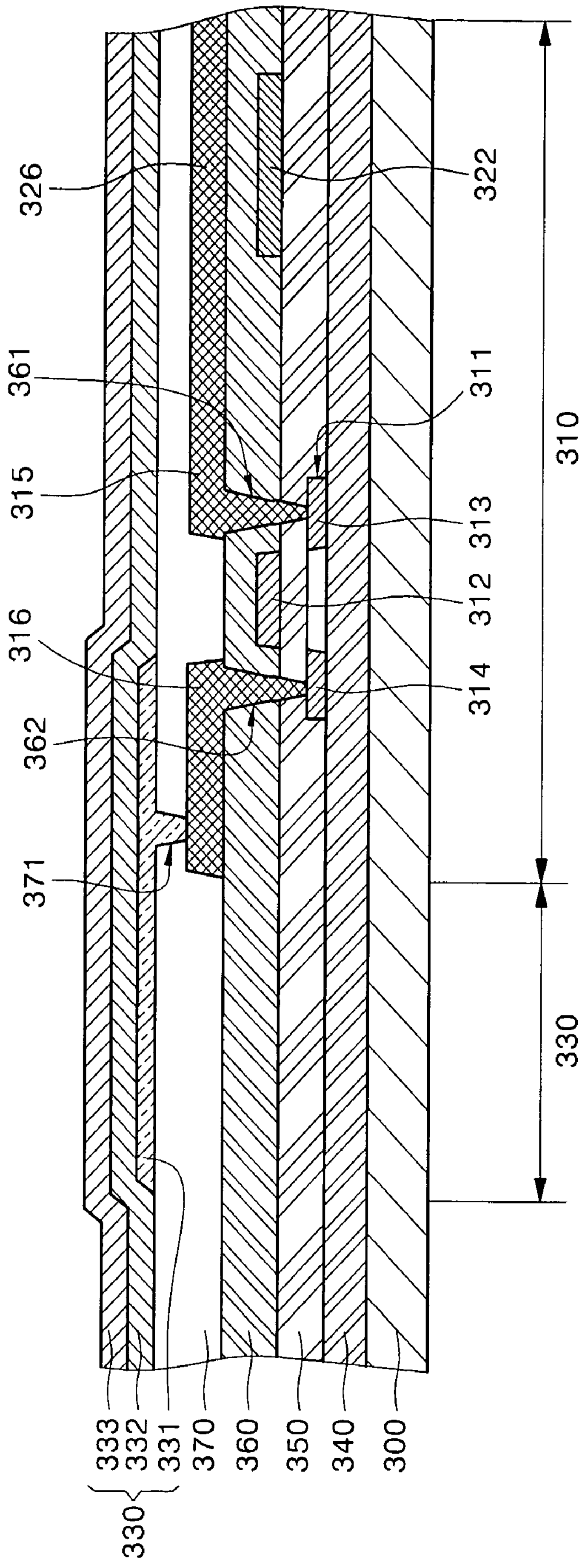
IV
IV
311
315
312
304
306
331a
331b
331

FIG. 3B


326
322
361
311
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332
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370
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340
300
330

FIG. 3C

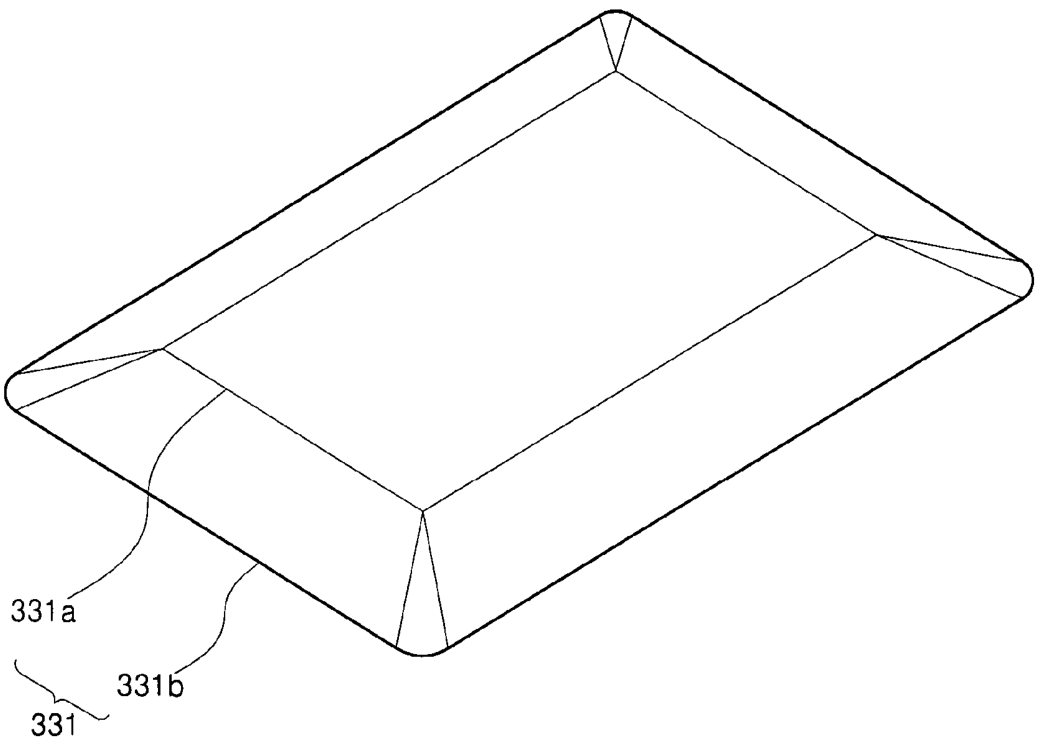


FIG. 3D

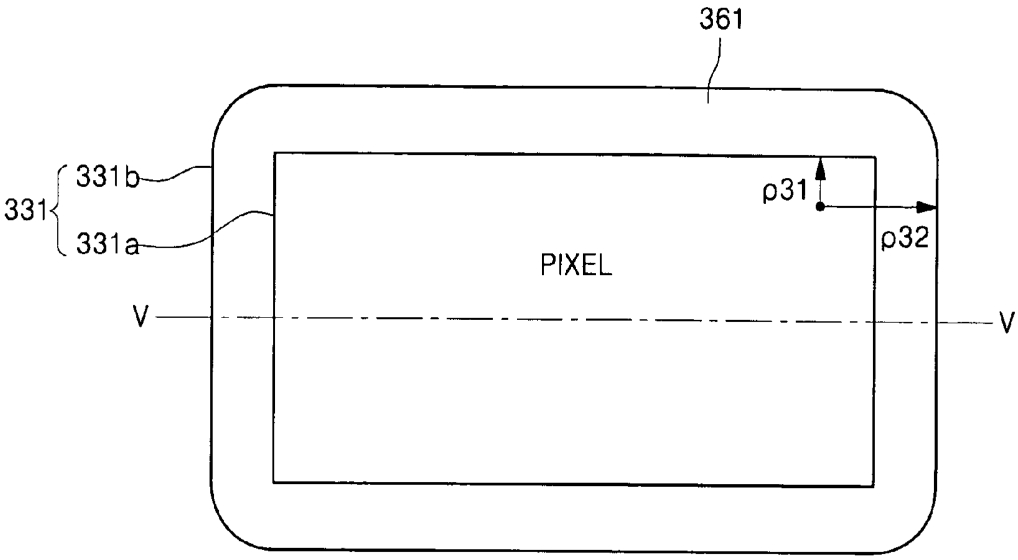


FIG. 3E

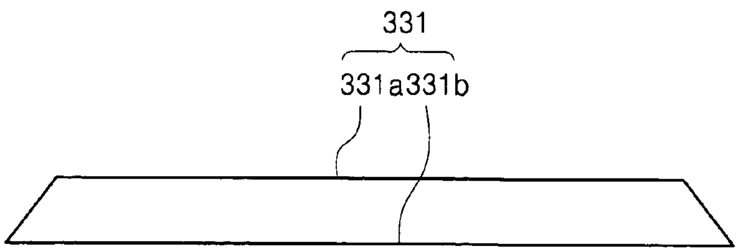
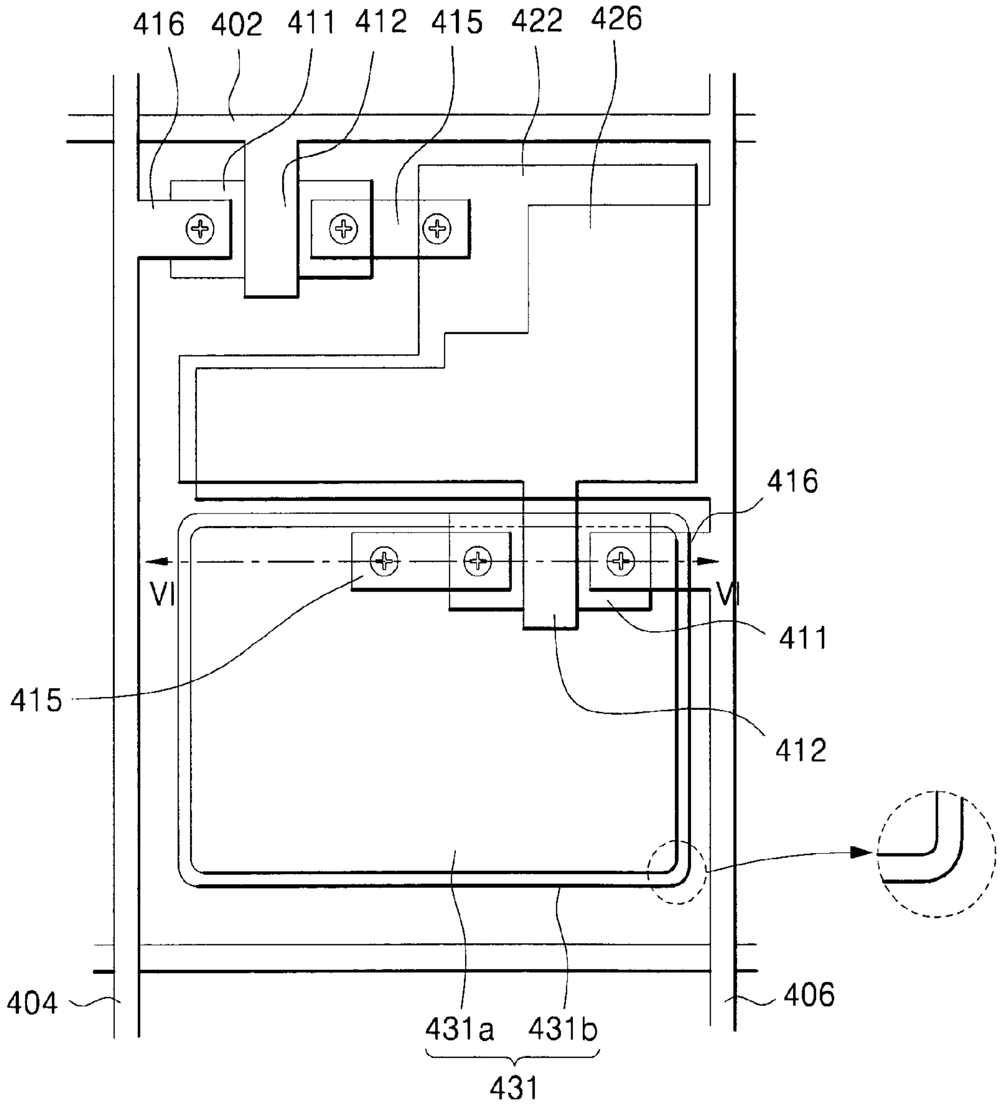


FIG. 4A


416
402
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426
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VI
VI
411
415
412
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406
431a
431b
431

FIG. 4B

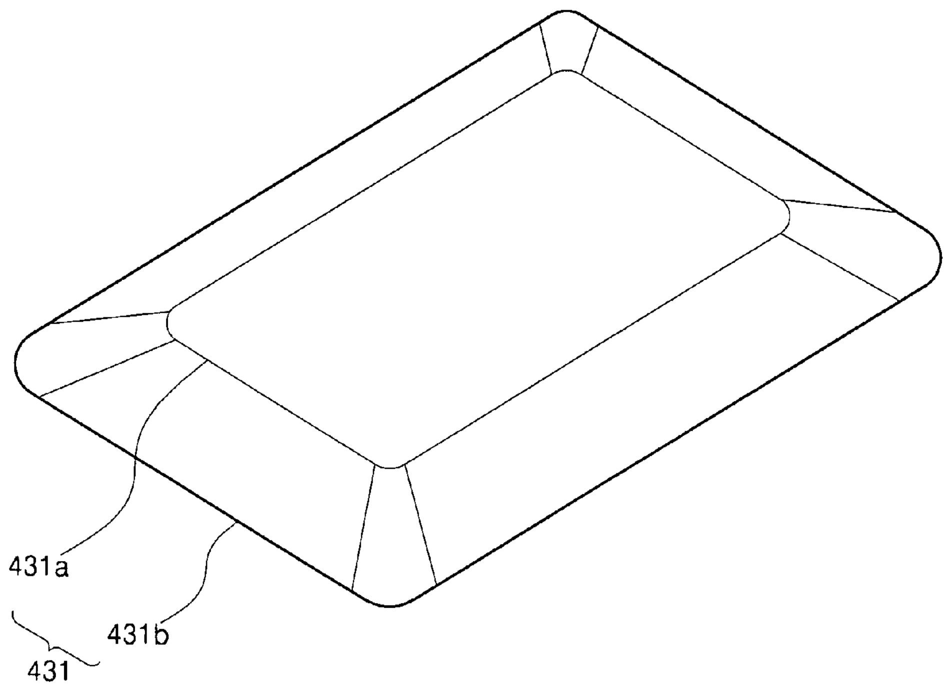


FIG. 4C

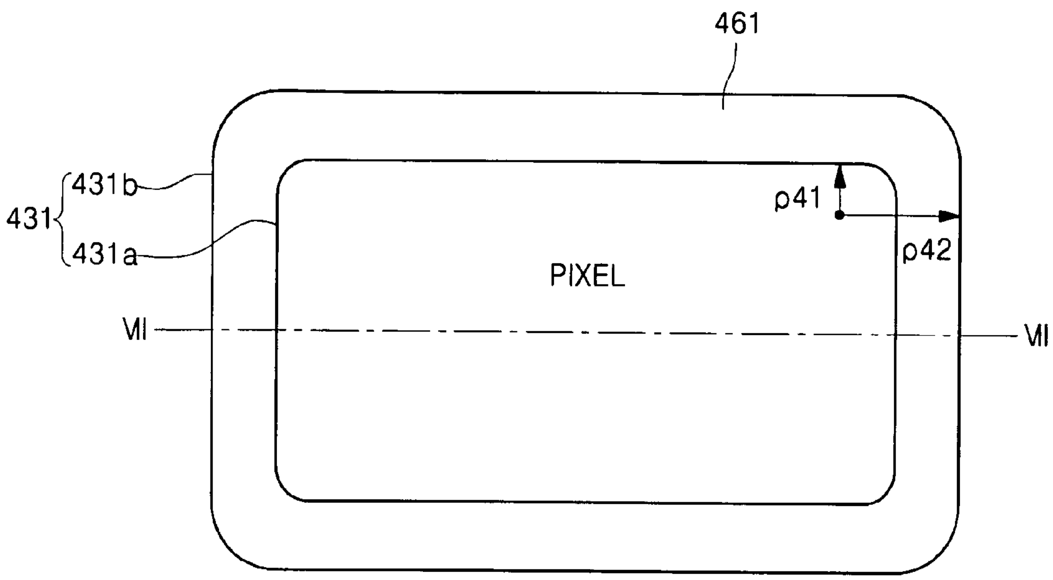
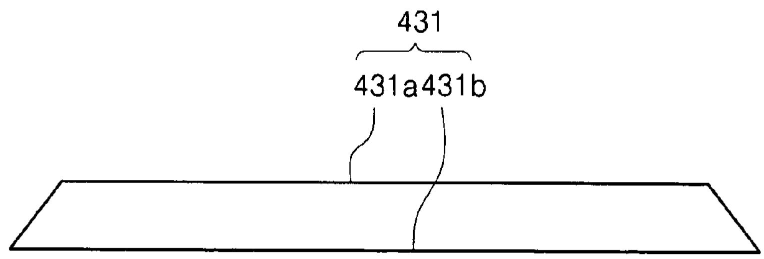


FIG. 4D



ORGANIC ELECTROLUMINESCENT DISPLAY DEVICE AND METHOD FOR MANUFACTURING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority of Korean Patent Application No. 2003-86154, filed Nov. 29, 2003, which is hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an organic electroluminescent display device and method for manufacturing the same. More particularly, the invention is directed to an organic electroluminescent display device and method for fabricating the same, in which corners of a lower (pixel) electrode are rounded off, thereby preventing contamination caused by outgassing and short-induced defects.

2. Description of the Related Art

With the development of active matrix organic light emitting devices (AMOLED) into flat panel display devices using organic electroluminescence devices (OELDs) and with application of AMOLEDs to mobile phones, great reduction in thickness, size and fabricating cost have been achieved.

FIG. **1**A shows a planar structure of a conventional AMOLED having two transistors and a capacitor. FIG. **1**B is a cross-sectional view taken along the line I-I of FIG. **1**A.

Referring to FIG. **1**B, the conventional AMOLED includes an emission region **110** and a non emission region **130**. In the emission region **110**, a lower electrode **131** (e.g., a pixel electrode), an organic emission layer **132** and an upper electrode **133** are formed. In the non-emission region **130** two thin film transistors (TFTS) and a capacitor are formed.

A buffer layer **140** is formed on a transparent insulating substrate **100** such as a glass substrate, and an amorphous silicon layer is deposited on the buffer layer to form a semiconductor layer **111**. The semiconductor layer **111** is formed by performing a crystallization process after patterning the deposited amorphous silicon layer. Then, a gate insulating layer **150** is formed on the entire surface of the substrate. Thereafter, a metallic material for a gate electrode is deposited and patterned on the gate insulating layer **150** to form a gate **112** on the semiconductor layer **111**. Additionally, a capacitor lower electrode **122** is simultaneously formed at this time. Upon formation of the gate **112** and the capacitor lower electrode **122**, a gate line **102** of FIG. **1**A is also formed.

Thereafter, source/drain regions **113** and **114** are formed by ion implantation of, for example, P or N type impurities, into the semiconductor layer **111**.

Next, an interlayer insulating layer **160** is formed on the entire surface of the substrate. Then the interlayer insulating layer **160** and the gate insulating layer **150** are etched to expose portions of the source/drain regions **113** and **114**, thereby forming contact holes **161** and **162** for source/drain electrodes.

Then, after a metallic material for the source/drain electrodes is deposited on the interlayer insulating layer **160**, the source/drain electrodes **115** and **116** are formed to contact with the source/drain regions **113** and **114** through the contact holes **161** and **162**. Then a capacitor upper electrode **126** is formed which extends from any one electrode, for example, the source electrode **115**, of the source/drain electrodes **115** and **116**; at the same time, a data line **104** and a power line **106** of FIG. **1**A are also formed.

Thereafter, a passivation layer **170** is formed on the interlayer insulating layer **160**. The passivation layer **170** is etched as to expose a portion of the other electrode, for example, the drain electrode **116**, of the source/drain electrodes **115** and **116**, thus forming a contact hole **171** for a pixel electrode.

Then, a transparent conductive layer is deposited on the passivation layer **170** and is patterned to form the lower electrode **131** contacting with the drain electrode **116** through the contact hole **171** for pixel electrode in the emission region **130**.

After an insulating layer **180** is formed on the passivation layer **170**, an opening **181** is formed to expose the lower electrode **131**. An organic emission layer **132** is formed on a planarization layer **180** including the opening **181**, and an upper electrode **133** is formed thereon.

In the conventional OLED, although the insulating layer **180** is similar to a pixel definition layer (PDL) defining the emission region, the PDL is commonly formed of an organic layer. However, a problem arises in that the organic emission layer **132** becomes contaminated due to outgassing. To address this problem, an organic light emitting display device may be formed without such pixel definition layer. However, another problem often experienced in conventional OLEDs formed without pixel definition layers is short-induced defects that generate a dark spot in their corresponding pixels.

For example, FIG. **2**A shows an embodiment of the planar structure of an organic light emitting display device without a pixel definition layer, and FIG. **2**B is a cross-sectional view taken along the line II-II of FIG. **2**A.

A method for manufacturing the organic light emitting display device without such pixel definition layer is now explained with reference to FIGS. **2**A and **2**B.

Referring to FIGS. **2**A and **2**B, a thin film transistor and a capacitor are formed on a non emission region **220** in the same manner and structure as illustrated in FIGS. **1**A and **1**B. Then, a lower electrode **261** is formed by depositing a transparent conductive layer in the emission region on the entire surface of a substrate so as to contact source/drain electrodes formed in the non-emission region through a contact hole **255***b* for pixel electrode and patterning the same.

Now, steps for forming the lower electrode **261** are illustrated through FIGS. **2**C to **2**E. FIG. **2**C is a perspective view showing the steps for forming the lower electrode **261**, FIG. **2**D is a plan view of the lower electrode **261**, and FIG. **2**E is a cross-sectional view taken along the line III-III of FIG. **2**D.

Referring to FIGS. **2**C to **2**E, corners of upper and lower portions of the lower electrode **261** are formed in an angle shape. As shown in FIG. **2**E, a length L**2** of the lower portion of the lower electrode **261** is formed longer than a length L**1** of the upper portion of the lower electrode **261**. That is, the lower electrode **261** has a side slanted at a tapered angle.

An organic emission layer **262** is formed on the lower electrode **261**. Then an upper electrode **263** made a metallic material is formed on the organic emission layer.

Upon the formation of the organic emission layer **262** on the lower electrode **261**, a step is formed. However, in use, a short-induced defect may be generated due to an open edge phenomenon. Thus, in the case where the upper and lower portions of the transparent conductive layer are angled, the organic emission layer **262** often deteriorates at its corner portion to expose the lower electrode **261**.

To address this problem, embodiments of the invention provide a lower pixel electrode having rounded corners.

Illustratively, FIG. **2**F shows an enlarged view of an emission region upon the generation of a short-induced defect.

SUMMARY OF THE INVENTION

The present invention is directed to an improved organic electroluminescent display device that has no pixel definition layer. Embodiments of the present invention also provide a method for fabricating the same, which prevents outgassing and short-induced defects by forming a lower (e.g. pixel) electrode having corners that are rounded off.

In one embodiment, an organic electroluminescent display device includes a thin film transistor formed in a non-emission region on an insulating substrate, which includes source/drain electrodes. The OELD further includes a lower electrode formed in an emission region on the insulating substrate and connected to one electrode of the source/drain electrodes through a contact hole. It also includes an organic emission layer formed in the emission region on the lower electrode, and an upper electrode formed on the organic emission layer, wherein the lower electrode has a surface with its corners rounded off.

In one embodiment, the lower electrode has an upper surface having a center of radius of curvature is at its corners so that the radius of curvature is zero. The lower surface of is the lower electrode has a center of radius of curvature at a point on the same axis as an axis perpendicular to a plane on which the center of radius of curvature of the upper surface is positioned so that the radius of curvature is larger than zero. In this manner, curvature is formed at all four corners of the upper and lower surfaces, respectively. In one embodiment, the upper electrode is a cathode electrode and the lower electrode is an anode electrode.

Another aspect of the present invention provides a method for manufacturing an organic electroluminescent display device. A thin film transistor having source/drain electrodes is formed in a non-emission region on an insulating substrate. A lower electrode is formed in an emission region on the insulating substrate and connected to one electrode of the source/drain electrodes through a contact hole. An organic emission layer is formed in the emission region on the lower electrode. An upper electrode is formed on the organic emission layer, wherein the corners of the lower electrode are rounded off.

The lower electrode has an upper surface whose surface has a rectangular shape in which the center of the radius of curvature is at its corners so that the radius of curvature is zero. The lower electrode also has a lower surface in which the center of the radius of curvature is at a point on the same axis as the center of the radius of curvature of the upper surface so that the radius of curvature of the lower surface is larger than zero, wherein curvature is formed at all four corners of the upper and lower surfaces, respectively.

The lower electrode has an upper surface whose surface is formed rounded and having the center of the radius of curvature at any point thereon, and a lower surface in which the center of the radius of curvature is at a point on the same axis as the center of the radius of curvature of the upper surface so that the radius of curvature of the lower surface is larger than that of the upper surface, wherein curvature is formed at all four corners of the upper and lower surfaces, respectively.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A shows a planar structure of a conventional AMOLED;

FIG. **1**B is a cross-sectional view taken along the line I-I of FIG. **1**A;

FIG. **2**A shows a planar structure of another conventional organic electroluminescent display device;

FIG. **2**B is a cross-sectional view taken along the line II-II of FIG. **2**A;

FIG. **2**C is a perspective view showing steps for forming the lower electrode of FIG. **2**A;

FIG. **2**D is a plan view of the lower electrode of FIG. **2**C;

FIG. **2**E is a cross-sectional view taken along the line III-III of FIG. **2**D;

FIG. **2**F is an enlarged photograph of the emission region upon generation of the short-induced defect;

FIG. **3**A shows a planar structure of an organic electroluminescent display device according to a first embodiment of the present invention;

FIG. **3**B is a cross-sectional view taken along the line IV-IV of FIG. **3**A;

FIG. **3**C is a perspective view showing steps for forming the lower electrode of FIG. **3**A;

FIG. **3**D is a plan view of the lower electrode of FIG. **3**C;

FIG. **3**E is a cross-sectional view taken along the line V-V of FIG. **3**D;

FIG. **4**A shows a planar structure of an organic electroluminescent display device according to a second embodiment of the present invention;

FIG. **4**B is a perspective view showing steps for forming the lower electrode of FIG. **4**A;

FIG. **4**C is a plan view of the lower electrode of FIG. **4**A; and

FIG. **4**D is a cross-sectional view taken along the line VII-VII of FIG. **4**C.

DETAILED DESCRIPTION OF THE INVENTION

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, 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 the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout the specification.

FIG. **3**A shows a planar structure of an active matrix organic electroluminescent display device (AMOLED) according to a first embodiment of the present invention. The AMOLED of FIG. **3**A illustrates a device consisting of two transistors and a capacitor.

FIG. **3**B shows a cross-sectional view taken along the line IV-IV of FIG. **3**A.

Referring to FIG. **3**B, in an AMOLED formed according to one embodiment of the present invention, a buffer layer **340** is formed on a transparent insulating substrate **300**, such as a glass substrate. The substrate includes a non-emission region **310** and an emission region **330**. Then, an amorphous silicon layer is deposited on the buffer layer **340** to form a semiconductor layer **311**. The semiconductor layer **311** is formed by performing a crystallization process after patterning the amorphous silicon layer. Then, a gate insulating layer **350** is formed on the entire surface of the substrate, and a metallic material for a gate electrode is deposited and patterned on the gate insulating layer **350** to form a gate **312** over the semiconductor layer **311**. A capacitor lower electrode **322** is simultaneously formed at this time. Now, upon the formation of the gate **312** and the capacitor lower electrode **322**, a gate line **302** of FIG. **3**A is also formed.

Thereafter, source/drain regions **313** and **314** are formed by ion implantation of, for example, P or N type impurities, into the semiconductor layer **311**.

Next, an interlayer insulating layer **360** is formed on the entire surface of the substrate, and the interlayer insulating layer **360** and the gate insulating layer **350** are etched to expose a portion of the source/drain regions **313** and **314**. Thereby, contact holes **361** and **362** for source/drain electrodes are formed.

Then, after a metallic material for the source/drain electrodes is deposited on the interlayer insulating layer **360**, the source/drain electrodes **315** and **316** are formed to contact with the source/drain regions **313** and **314** through the contact holes **361** and **362**. Here, a capacitor upper electrode **326** is formed which extends from any one electrode, for example, the source electrode **315**, of the source/drain electrodes **315** and **316**, and at the same time, a data line **304** and a power line **306** of FIG. **3**A are also formed.

Thereafter, a passivation layer **370** is formed on the interlayer insulating layer **360**. The passivation layer **370** is etched to expose a portion of the other electrode, for example, the drain electrode **316**, of the source/drain electrodes **315** and **316**, thus forming a contact hole **371** for a pixel electrode.

Then, a transparent conductive layer is deposited on the passivation layer **370** in an emission region **330**, and is patterned to form a lower electrode **331** contacting with the drain electrode **316** through the contact hole **371** for the pixel electrode.

Now, steps for forming the lower electrode **331** of FIG. **3**A are illustrated through FIGS. **3**C to **3**E.

FIG. **3**C is a perspective view showing a whole shape of the lower electrode **331**, FIG. **3**D is a plan view of the lower electrode **331**, and FIG. **3**E is a cross-sectional view taken along the line V-V of FIG. **3**D.

As shown in FIGS. **3**C to **3**E, it can be understood that the upper surface **331***a* of the lower electrode **331** has a rectangular shape, and a lower surface **331***b* of the lower electrode **331** has rounded corners, so that the lower electrode **331** is tapered.

This can be expressed as following equation.

$$e_{31}=0, e_{3232}>0$$

Here, e_{31} is the radius of curvature of the upper surface **331***a*, and e_{32} is the radius of curvature of the lower surface **331***b*. The lower electrode **331** has the upper surface **331***a* in which the center of the radius of curvature e_{31} is at its corners so that the radius of curvature is zero. Meanwhile, the center of the radius of curvature e_{32} of the lower surface **331***b* is located at a point on the same axis as an axis perpendicular to a plane on which the center of the radius of curvature of the upper surface **331***a* is positioned so that the radius of curvature e_{32} is larger than zero. Thus, upper surface **331***a* has four angled corners and the lower surface **331***b* has four rounded corners. Accordingly, since the four corners of the lower electrode **331** are not angled, an open edge defect due to cut-off of the organic emission layer **332** can be prevented even after the organic emission layer **332** is deposited.

Next, an organic emission layer **332** is formed on the passivation layer **370** including the lower electrode **331**. Thereafter, an upper electrode **333** made of a metallic material is formed thereon, thereby creating the active matrix organic electroluminescent display device.

In the embodiment just described, the lower electrode acts as an anode electrode and the upper electrode acts as a cathode electrode.

FIG. **4**A shows a planar structure of an active matrix organic electroluminescent display device (AMOLED) according to a second embodiment of the present invention. The AMOLED of FIG. **4**A illustrates a device having two transistors and a capacitor.

A cross-sectional view taken along the line VI-VI of FIG. **4**B illustrates structure similar to that shown in FIG. **3**B. Additionally, a method of manufacturing the second embodiment of the present invention will be easily understood by a person skilled in the art with reference to the above description given with regard to the first embodiment. Thus, FIG. **4**A need not be described in detail.

However, the steps of an exemplary method for forming the lower electrode **431** of FIG. **4**A are explained with reference to FIGS. **4**B to **4**D.

FIG. **4**B is a perspective view showing a whole shape of the lower electrode **431**, FIG. **4**C is a plan view of the lower electrode **431**, and FIG. **4**D is a cross-sectional view taken along the line VII-VII of FIG. **4**C.

Upon the formation of the lower electrode **431**, shown in FIG. **4**C, four corners of an inner portion of an upper surface **431***a* are rounded on a plane, four corners of an outer portion of a lower surface **431***b* are rounded. As shown in FIG. **4**D, the lower electrode is formed to be tapered so that the lower surface **431***b* is formed wider than upper surface **431***a*.

This can be expressed as following equation.

$$e_{42}>0, e_{41}>0$$

Here, e_{41} is the radius of curvature of the upper surface **431***a* of the lower electrode **431**, and e_{42} is the radius of curvature of the lower surface **431***b* of the lower electrode **431**.

The lower electrode **431** has the upper surface **431***a* whose four corners each have curvature and the center of the curvature is positioned on the upper surface **431***a*. The center of the radius of curvature e_{42} of the lower surface **431***b* is at a point on the same axis as an axis perpendicular to a plane including the center of the radius of curvature e_{41} of the upper surface **431***a*, wherein the radius of curvature e_{42} of the lower surface **431***b* is larger than that of the upper surface **431***a*, and the four corners of the lower surface **431***b* are also rounded. Thus, four corners of the upper surface **431***a* and the lower surface **431***b* as well of the lower electrode are rounded, so that an open edge defect due to cut-off of the organic emission layer (see **332** of FIG. **3**B) is further prevented even after the organic emission layer is deposited.

The upper electrode (see **333** of FIG. **3**B) is formed on the organic emission layer (**332** of FIG. **3**B) to supply a common power source.

In this embodiment, the lower electrode **431** is an anode electrode and the upper electrode formed on the organic emission layer is a cathode electrode.

Although several embodiments of the present invention have been described above, curvature of the lower electrode may also be provided at a side portion so that a shape of the surface of the lower electrode forms an oval or circular shape.

According to the embodiment of the present invention as described above, in manufacturing an AMOLED having no pixel definition layer, the lower electrode is formed of a transparent metallic material and has the corners of its upper and lower surfaces rounded off, to prevent outgassing and short-induced defects. Such a configuration improves luminosity and increases the life of the organic electroluminescent display device.

Although preferred embodiments of the present invention have been described for illustrative purposes, those skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims.

What is claimed is:

1. An organic electroluminescent display device, comprising:

a thin film transistor formed in a non-emission region on an insulating substrate and having source and drain electrodes;

a lower electrode formed in an emission region on the insulating substrate and connected to one electrode of the source and drain electrodes through a contact hole;

an organic emission layer formed in the emission region on the lower electrode; and

an upper electrode formed on the organic emission layer,

wherein the lower electrode has a surface with its corners rounded off, and

wherein the lower electrode has an upper surface in which a center of radius of curvature is at its corners so that the radius of curvature is zero, and a lower surface in which the center of radius of curvature is at a point on the same axis as an axis perpendicular to a plane on which the center of radius of curvature of the upper surface is positioned so that the radius of curvature is larger than zero.

2. The organic electroluminescent display device as claimed in claim **1**, wherein curvature is formed at all four corners of the upper and lower surfaces, respectively.

3. The organic electroluminescent display device as claimed in claim **1**, wherein the upper electrode acts as a cathode electrode and the lower electrode acts as an anode electrode.

4. An organic electroluminescent display device, comprising:

a thin film transistor formed in a non-emission region on an insulating substrate and having source and drain electrodes;

a lower electrode formed in an emission region on the insulating substrate and connected to one electrode of the source and drain electrodes through a contact hole;

an organic emission layer formed in the emission region on the lower electrode; and

an upper electrode formed on the organic emission layer,

wherein the lower electrode has a surface with its corners rounded off, and

wherein the lower electrode has an upper surface whose corners have curvature whose center is positioned on the upper surface, and a lower surface in which the center of the radius of curvature is at a point on the same axis as an axis perpendicular to a plane including the center of the radius of curvature of the upper surface, wherein the radius of curvature of the lower surface is larger than that of the upper surface.

5. The organic electroluminescent display device as claimed in claim **4**, wherein curvature is formed at all four corners of the upper and lower surfaces, respectively.

6. The organic electroluminescent display device as claimed in claim **4**, wherein the upper electrode acts as a cathode electrode and the lower electrode acts as an anode electrode.

7. A method for manufacturing an organic electroluminescent display device, the method comprising the steps of:

forming a thin film transistor having source/drain electrodes in a non-emission region on an insulating substrate;

forming a lower electrode in an emission region on the insulating substrate to be connected to one electrode of the source/drain electrodes through a contact hole;

forming an organic emission layer in the emission region on the lower electrode; and

forming a cathode electrode on the organic emission layer,

wherein the lower electrode has a surface with its corners rounded off, and

wherein the lower electrode has an upper surface whose surface is formed rectangular in which the center of the radius of curvature is at its corners so that the radius of curvature is zero, and a lower surface in which the center of the radius of curvature is at a point on the same axis as the center of the radius of curvature of the upper surface so that the radius of curvature of the lower surface is larger than zero.

8. The method as claimed in claim **7**, wherein curvature is formed at all four corners of the upper and lower surfaces, respectively.

9. A method for manufacturing an organic electroluminescent display device, the method comprising the steps of:

forming a thin film transistor having source/drain electrodes in a non-emission region on an insulating substrate;

forming a lower electrode in an emission region on the insulating substrate to be connected to one electrode of the source/drain electrodes through a contact hole;

forming an organic emission layer in the emission region on the lower electrode; and

forming a cathode electrode on the organic emission layer,

wherein the lower electrode has a surface with its corners rounded off, and

wherein the lower electrode has an upper surface whose surface is formed rounded and having the center of the radius of curvature at any point thereon, and a lower surface in which the center of the radius of curvature is at a point on the same axis as the center of the radius of curvature of the upper surface so that the radius of curvature of the lower surface is larger than that of the upper surface.

10. The method as claimed in claim **9**, wherein curvature is formed at all four corners of the upper and lower surfaces, respectively.

* * * * *

专利名称(译)	有机电致发光显示装置及其制造方法		
公开(公告)号	[US7294962](US7294962)	公开(公告)日	2007-11-13
申请号	US10/937294	申请日	2004-09-10
[标]申请(专利权)人(译)	KIM HYUN MU 基姆Kyong做		
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[标]发明人	KIM MU HYUN KIM KYONG DO		
发明人	KIM, MU-HYUN KIM, KYONG-DO		
IPC分类号	H05B33/00 H05B33/26 H01L27/32 H01L51/50 H01L51/52 H05B33/10		
CPC分类号	H01L51/5206 H01L27/3244 H01L51/5209		
审查员(译)	WILLIAMS，JOSEPH		
优先权	1020030086154 2003-11-29 KR		
其他公开文献	US20050116623A1		
外部链接	Espacenet USPTO		

摘要(译)

本发明涉及一种改进的有机电致发光器件。在一个实施例中，OLED包括形成在绝缘衬底上的非发射区域中的薄膜晶体管，该绝缘衬底还包括源极和漏极。 OLED还包括下电极，该下电极形成在绝缘基板上的发光区域中并且通过接触孔连接到源/漏电极的一个电极。 OLED还包括形成在下电极上的发光区域中的有机发光层，以及形成在有机发光层上的上电极，其中下电极具有其角部倒圆的表面。下电极用作像素电极。使其表面具有圆角，防止由于除气引起的短引起的缺陷。