



US011150522B2

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

(10) **Patent No.:** **US 11,150,522 B2**

(45) **Date of Patent:** **Oct. 19, 2021**

(54) **DISPLAY DEVICE**

(2021.01); *G02F 1/133345* (2013.01); *G02F 1/134363* (2013.01); *G02F 2201/56* (2013.01)

(71) Applicant: **Japan Display Inc.**, Tokyo (JP)

(58) **Field of Classification Search**

(72) Inventors: **Junko Nagasawa**, Tokyo (JP); **Hideki Shiina**, Tokyo (JP)

CPC *G02F 1/1339*; *G02F 1/13394*; *G02F 1/13396*; *G02F 2001/13398*; *G02F 1/133377*

(73) Assignee: **Japan Display Inc.**, Tokyo (JP)

See application file for complete search history.

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

(56) **References Cited**

U.S. PATENT DOCUMENTS

(21) Appl. No.: **16/953,573**

2010/0079718 A1* 4/2010 Sekiya *G02F 1/133512*
349/153
2016/0011633 A1* 1/2016 Watanabe *G09G 3/3648*
345/184
2016/0202515 A1* 7/2016 Watanabe *G06F 1/169*
349/153

(22) Filed: **Nov. 20, 2020**

(65) **Prior Publication Data**

US 2021/0088826 A1 Mar. 25, 2021

* cited by examiner

Related U.S. Application Data

Primary Examiner — Mariam Qureshi

(63) Continuation of application No. 16/566,983, filed on Sep. 11, 2019, now Pat. No. 10,877,321, which is a continuation of application No. 15/412,514, filed on Jan. 23, 2017, now Pat. No. 10,451,926.

(74) *Attorney, Agent, or Firm* — Michael Best & Friedrich LLP

(30) **Foreign Application Priority Data**

Feb. 5, 2016 (JP) 2016-020679

(57) **ABSTRACT**

(51) **Int. Cl.**

G02F 1/1339 (2006.01)
G02F 1/1343 (2006.01)
G02F 1/1341 (2006.01)
G02F 1/1333 (2006.01)
G02F 1/1368 (2006.01)

A liquid crystal display device includes a first substrate, a second substrate, a liquid crystal sandwiched between the substrates, and a display region. A hole portion is formed in the display region. A first seal portion is formed to surround the display region. A second seal portion is formed to surround the hole portion. The first and the second seal portions seal the liquid crystal. The second seal portion has a first end portion on the liquid crystal side and a second end portion on the opposite side of the liquid crystal side. A sealing material is present in the first end portion. A sealing material is present in the second end portion. A wall-like spacer is formed between the first and the second end portions to surround the hole portion. The wall-like spacer defines the gap between the first and the second substrates.

(52) **U.S. Cl.**

CPC *G02F 1/13394* (2013.01); *G02F 1/1339* (2013.01); *G02F 1/1341* (2013.01); *G02F 1/1368* (2013.01); *G02F 1/13396* (2021.01); *G02F 1/13398* (2021.01); *G02F 1/13415*

9 Claims, 10 Drawing Sheets

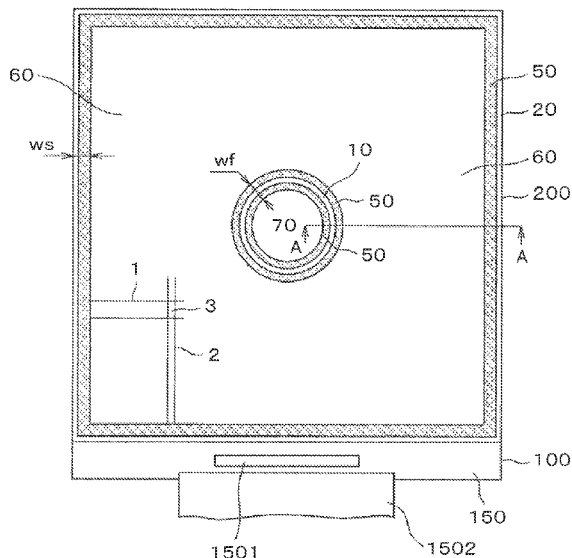


FIG. 1

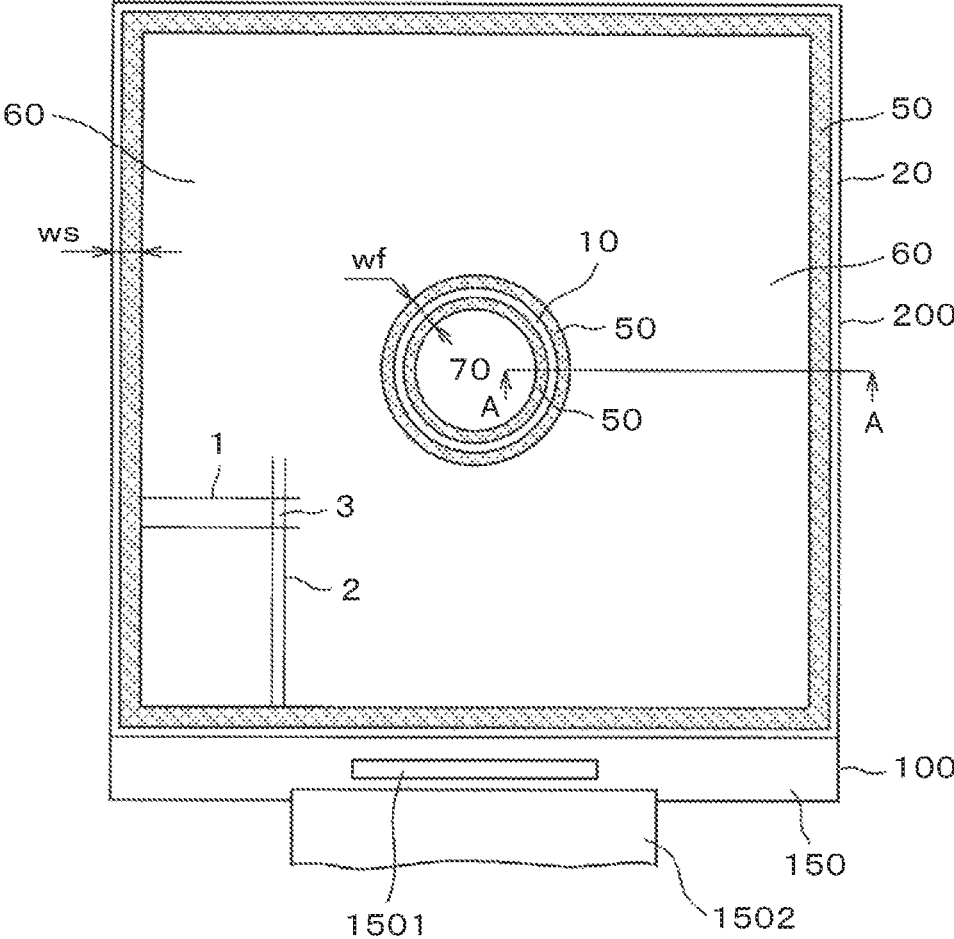


FIG. 2

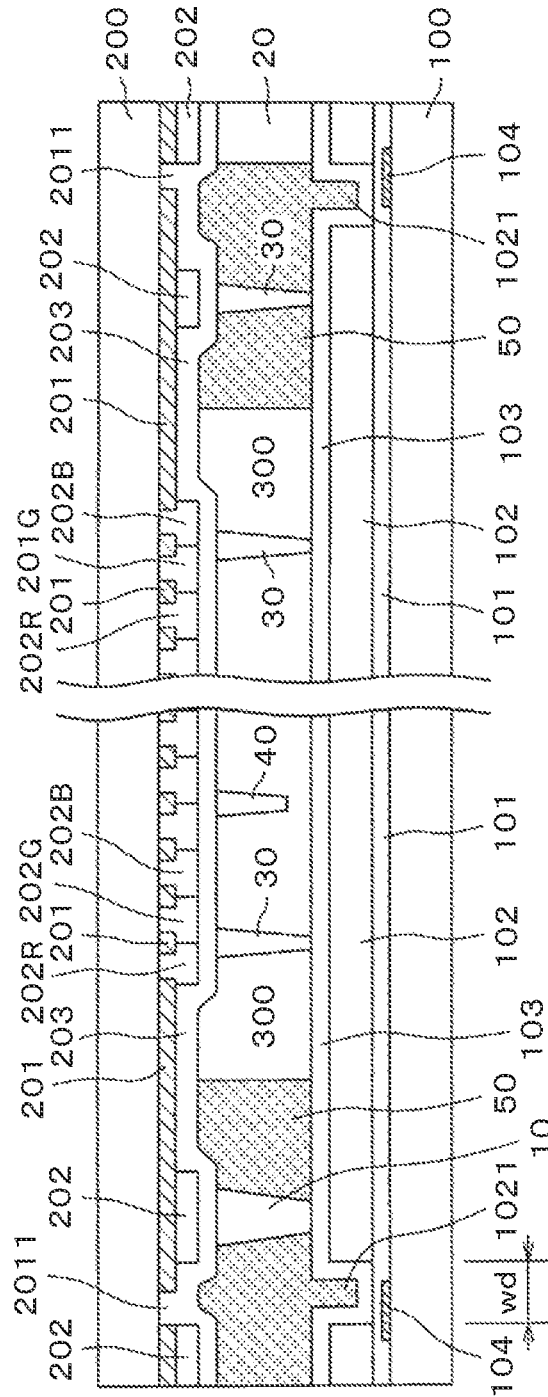


FIG. 3

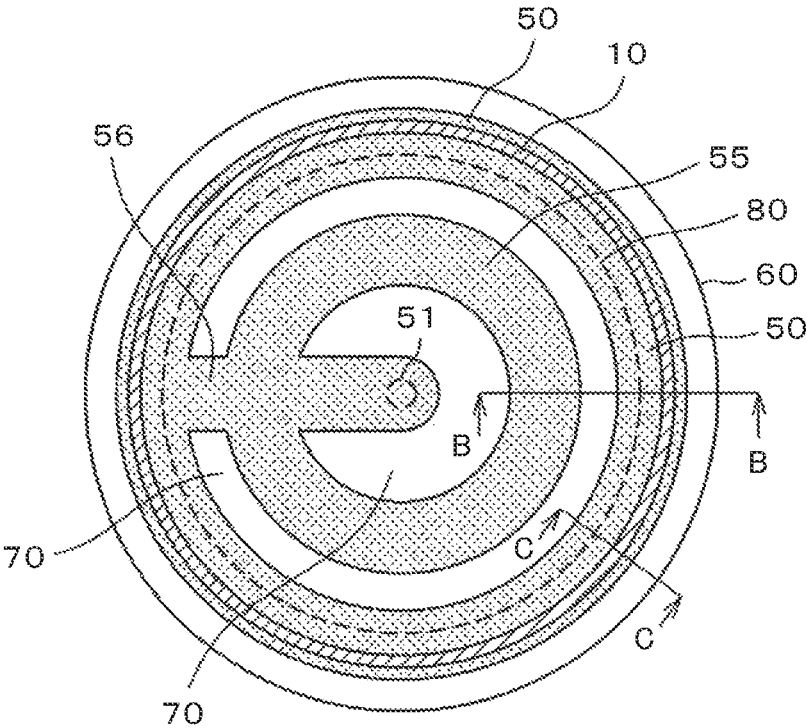


FIG. 4

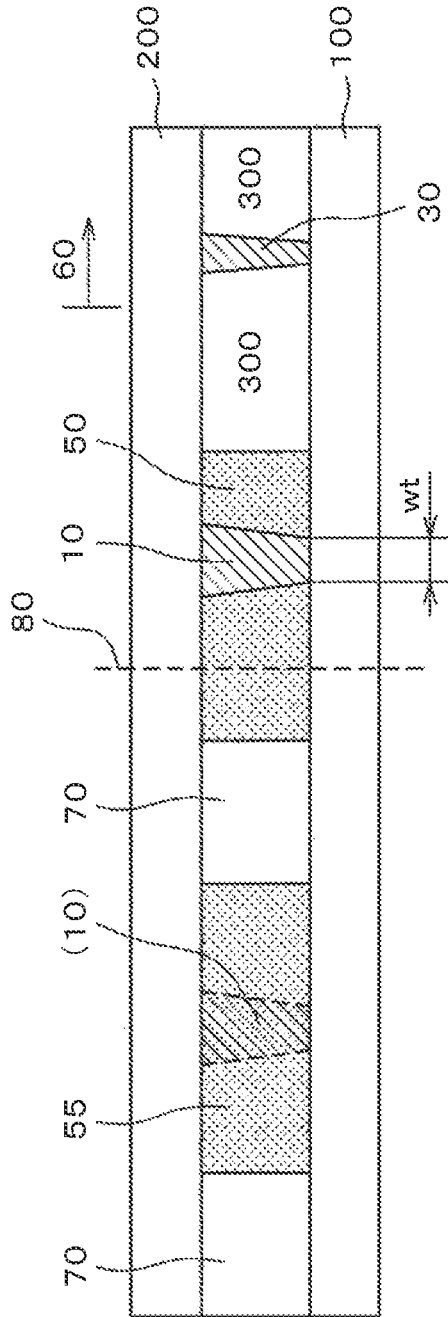


FIG. 5A

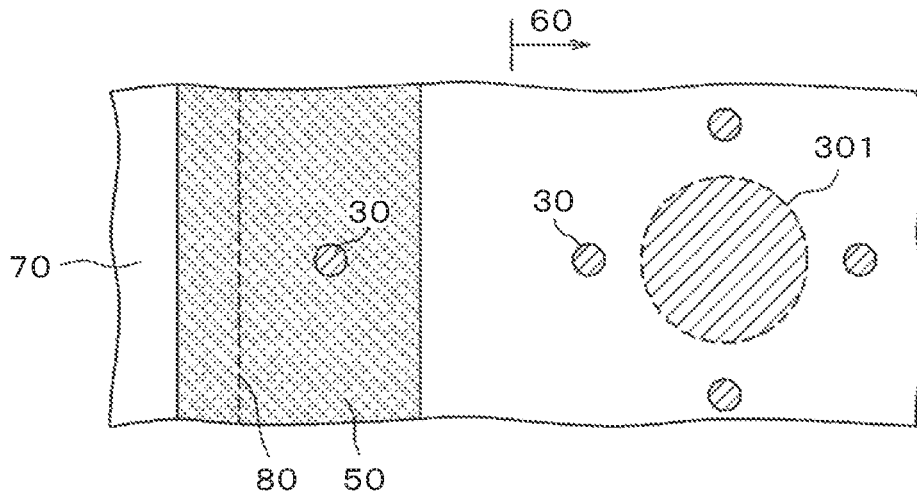


FIG. 5B

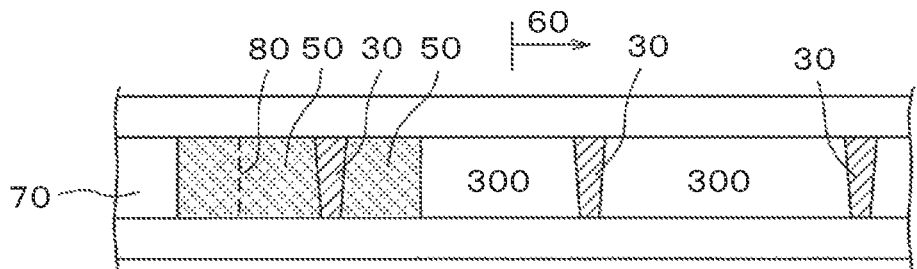


FIG. 5C

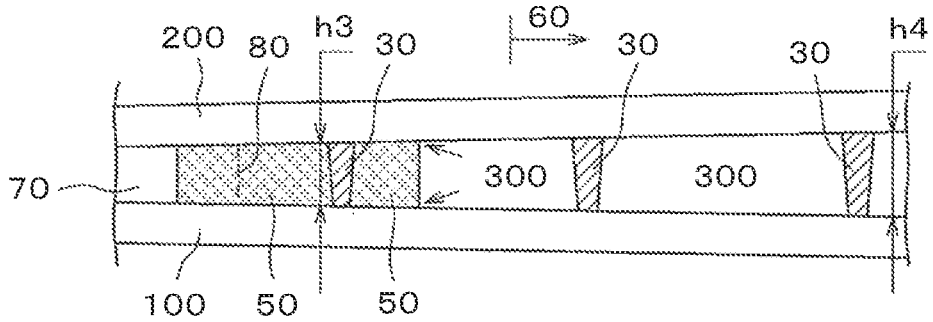


FIG. 6A

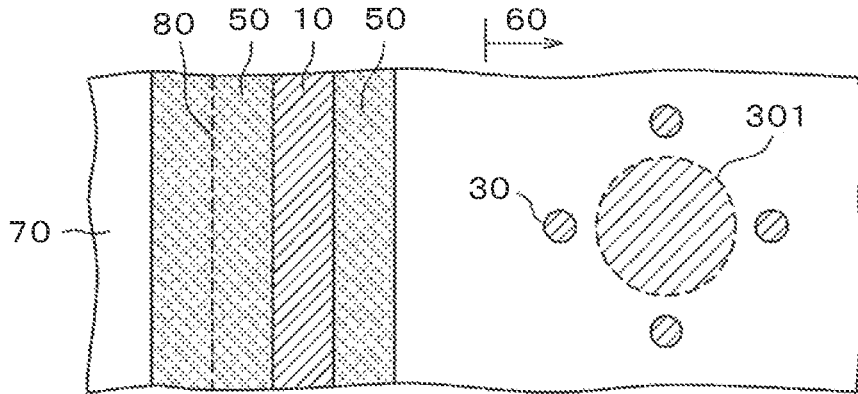


FIG. 6B

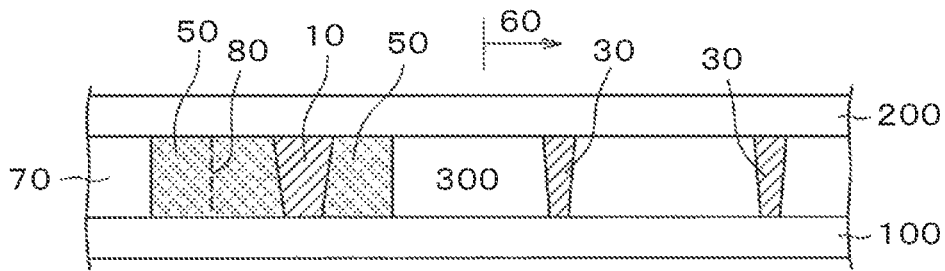


FIG. 6C

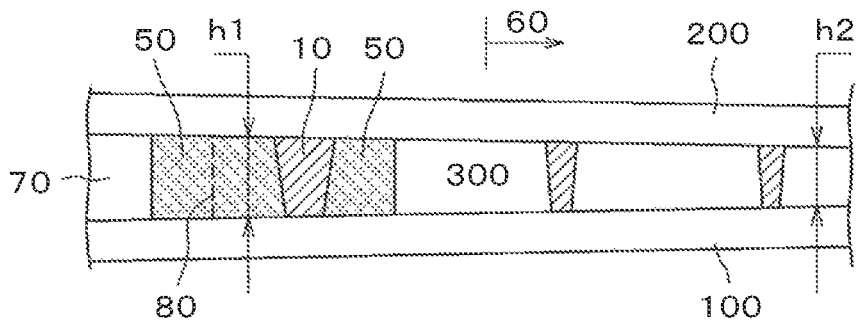


FIG. 7

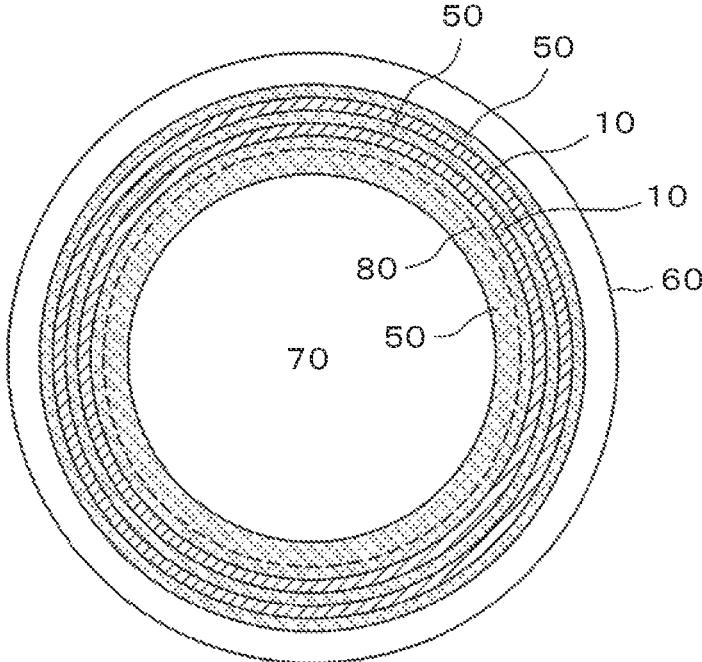


FIG. 8

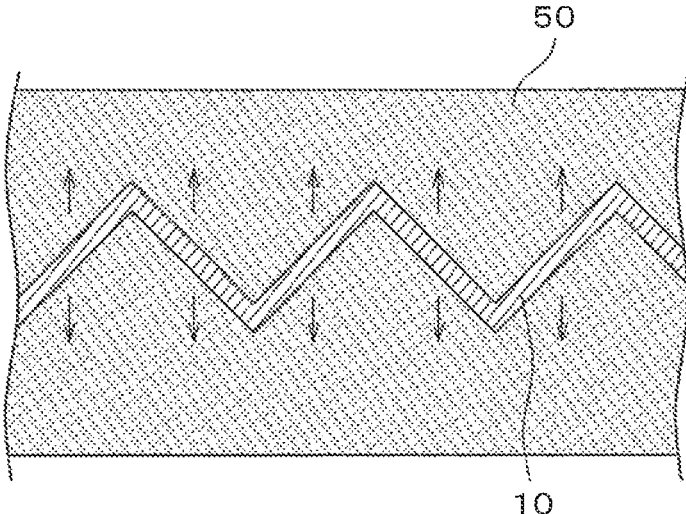


FIG. 9

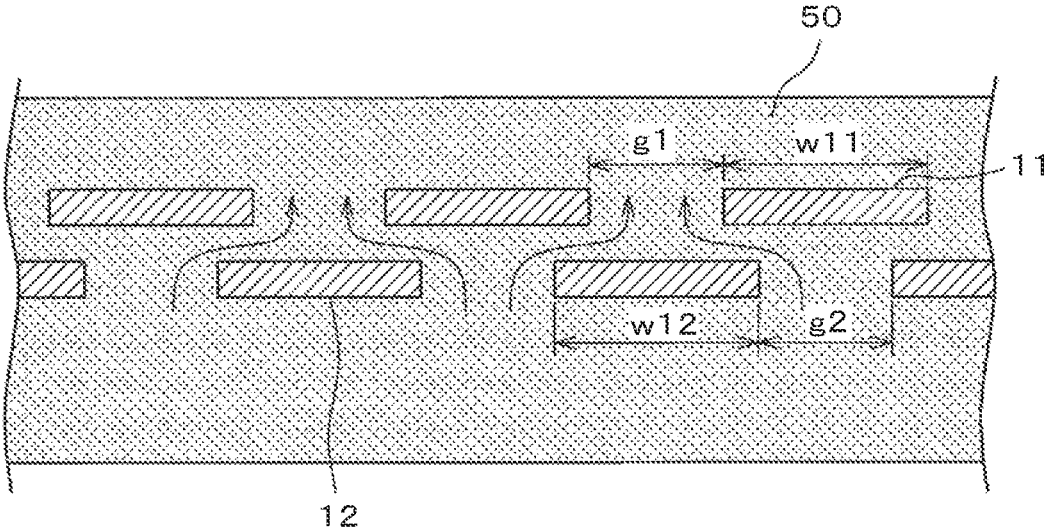


FIG. 10

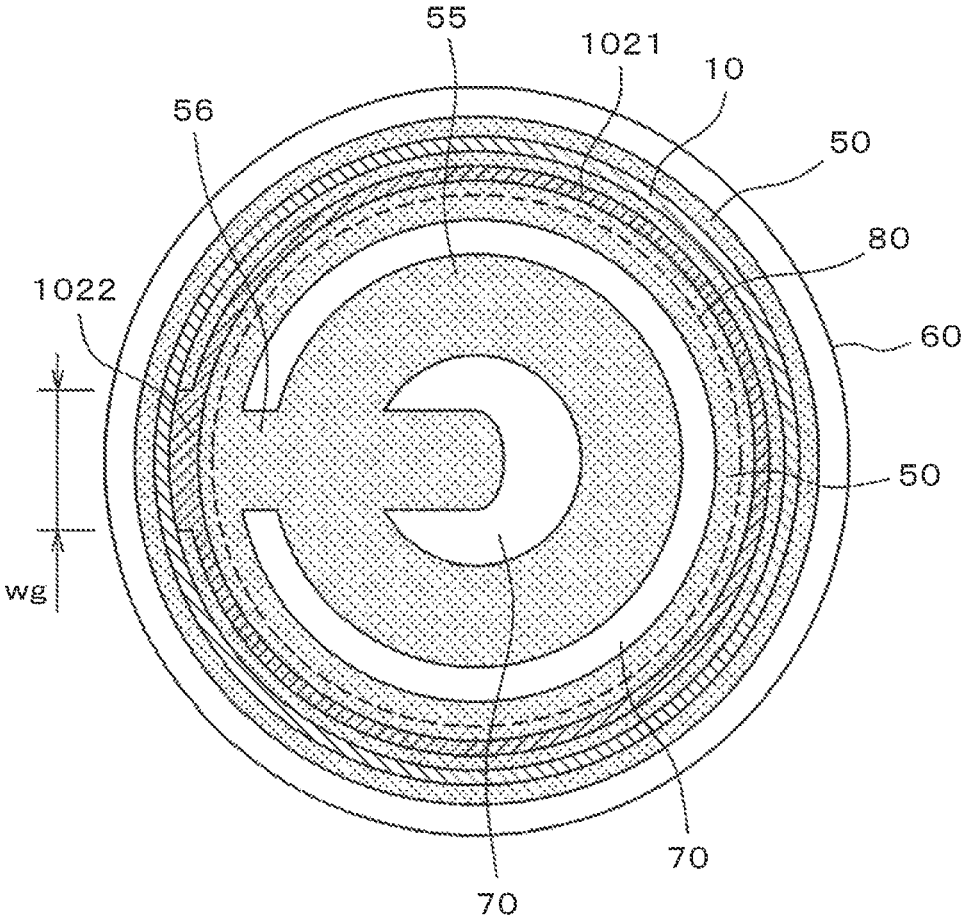


FIG. 11

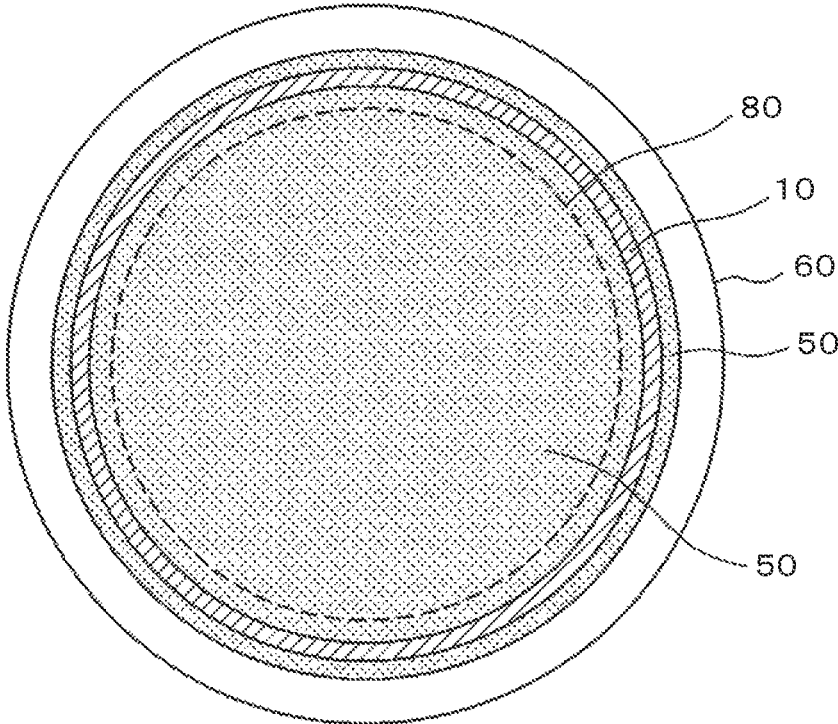
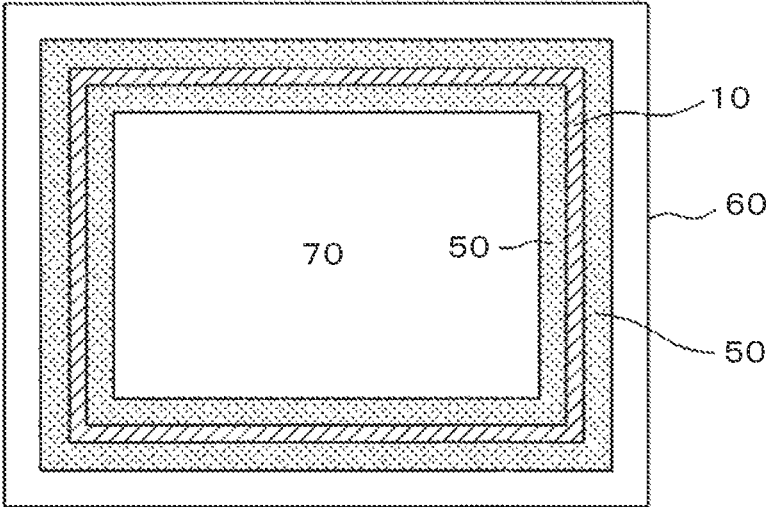


FIG. 12



DISPLAY DEVICE**CROSS-REFERENCE TO RELATED APPLICATIONS**

This application is a continuation of U.S. patent application Ser. No. 16/566,983, filed on Sep. 11, 2019, which, in turn, is a continuation of U.S. patent application Ser. No. 15/412,514, (now U.S. Pat. No. 10,451,926) filed on Jan. 23, 2017. Further, this application claims priority from Japanese Patent Application JP 2016-020679 filed on Feb. 5, 2016, the entire contents of which are hereby incorporated by reference into this application.

BACKGROUND OF THE INVENTION**Field of the Invention**

The present invention relates to a display device having a region surrounded by a display region.

Description of the Related Art

A liquid crystal display device includes a thin film transistor (TFT) substrate and a counter substrate disposed opposite to the TFT substrate. The TFT substrate includes pixels each having a pixel electrode, a TFT, and other elements in a matrix configuration. The TFT substrate is attached to the counter substrate with a sealing material formed on the edge portions of the substrates. On the inner side of the sealing material, a liquid crystal is sandwiched between the TFT substrate and the counter substrate. Images are formed by controlling the light transmittance of liquid crystal molecules in each pixel.

In thin, flat display devices, such as liquid crystal display devices, there is a demand that a space (a hole) penetrated through a region surrounded by a display region is provided and the hole is used for fixing the display region or for providing another member. In other words, for convenience of the manufacturing process steps of the liquid crystal display device, it is efficient to form holes on the TFT substrate and the counter substrate at the same time.

In the display, as techniques of forming holes on a glass substrate, there is a technique in which a hole is formed on one of the glass substrates configuring a plasma display device and the hole is used as an exhaust hole or an inlet hole for a gas, such as Ne and Xe. Japanese Unexamined Patent Application Publication No. 2006-305672 describes a technique of forming an exhaust hole on one of the glass substrates of a plasma display device using a drill having diamond abrasive grains.

SUMMARY OF THE INVENTION

A space (in the following, also referred to as a hole) surrounded by the display region of a screen is formed after the completion of a liquid crystal display panel. In other words, a sealing material is formed on a portion corresponding to the outer shape of the hole, and holes are opened on a counter substrate and a TFT substrate the same time using a glasscutter, a glass drill, or other devices. In order to open the holes on the counter substrate and the TFT substrate at the same time, it is desirable to form a sealing material on at least a portion from which glass is cut.

On the other hand, since it is inefficient to form liquid crystal display panels one by one, a large number of liquid crystal display panels are formed on a mother substrate, and

the mother substrate is separated into individual liquid crystal display panels by scribing. Scribing is a method in which portions corresponding to the outer shapes of the liquid crystal display panels are scribed and an impact is applied to the scribed portions to cut glass. Therefore, no sealing material is preferably present on the scribed portions.

In other words, a seal portion that defines the outer shape of the liquid crystal display panel has a seal structure different from the seal structure of a seal portion formed on the hole portion on the liquid crystal display panel. For example, in the liquid crystal display panel, after a liquid crystal is dropped onto the display region, a mother counter substrate is attached to a mother TFT substrate in a reduced pressure, and then the mother substrates are returned in the atmosphere. The reason why the pressure is reduced is that no bubbles to be contained when the liquid crystal is sealed.

After the mother substrates (a plurality of liquid crystal display panels) are returned from the reduced pressure to the atmosphere, the substrates are deformed. However, degrees of deformation are different among the outer seal portion, the display region, and the hole seal portion. Specifically, in the hole seal portion, a problem arises in that the liquid crystal is entered between the seal portion and the substrates. The present invention is to cope with this problem.

The present invention is to solve the problem.

Main specific schemes are as below. In other words, an aspect of the present invention a liquid crystal display device including: a first substrate; a second substrate; and a liquid crystal sandwiched between the first and the second substrates. In the liquid crystal display device, on the first substrate and on the second substrate, a hole portion is formed. On the first substrate and on the second substrate, a first seal portion is formed on an outer side of a display region. Between the hole portion and the display region, a second seal portion is formed. The second seal portion has a first end portion on the liquid crystal side and a second end portion on the hole portion side. A sealing material is present on the second end portion. Between the first end portion and the second end portion, a spacer is formed so as to surround the hole portion, and the spacer defines a gap between the first and the second substrates.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of a liquid crystal display device according to an embodiment of the present invention;

FIG. 2 is a cross-sectional view taken along line A-A in FIG. 1;

FIG. 3 is a plan view of a state before a hole portion is removed;

FIG. 4 is a cross-sectional view taken along line B-B in FIG. 3;

FIG. 5A is a plan view of a liquid crystal dropping process in the case in which the present invention is not used;

FIG. 5B is a cross-sectional view of a state in which a TFT substrate is attached to a counter substrate under a reduced pressure in the case in which the present invention is not used;

FIG. 5C is a cross-sectional view of a state of the TFT substrate and the counter substrate under an atmospheric pressure in the case in which the present invention is not used;

FIG. 6A is a plan view of a liquid crystal dropping process according to an embodiment of the present invention;

3

FIG. 6B is a cross-sectional view of a state in which a TFT substrate is attached to a counter substrate under a reduced pressure according to an embodiment of the present invention;

FIG. 6C is a cross-sectional view of a state of the TFT substrate and the counter substrate under an atmospheric pressure according to an embodiment of the present invention;

FIG. 7 is a plan view of a region near a hole portion according to another embodiment of the present invention;

FIG. 8 is a plan view of another embodiment of the shape of a wall-like spacer;

FIG. 9 is a plan view of still another embodiment of the shape of the wall-like spacer;

FIG. 10 is a plan view of an exemplary shape of a groove of an organic passivation film of a hole seal portion;

FIG. 11 is a plan view of another example of a shape before a hole portion is formed; and

FIG. 12 is a plan view of an example of a rectangular hole portion.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 is a plan view of a liquid crystal display panel to which an embodiment of the present invention is applied. In FIG. 1, a TFT substrate 100 is attached to a counter substrate 200 with a sealing material 50, and a liquid crystal is sandwiched between the TFT substrate 100 and the counter substrate 200. The TFT substrate 100 is formed greater than the counter substrate 200. A portion where only the TFT substrate 100 is provided is a terminal portion 150. On the terminal portion 150, a driver IC 1501 that drives a liquid crystal display panel is mounted, and a flexible circuit board 1502 that supplies power, picture signals, scanning signals, and the like is connected to the liquid crystal display panel.

In FIG. 1, in the display region 60, scanning lines 1 extend in a first direction, and are arrayed in a second direction. Picture signal lines 2 extend in the second direction, and are arrayed in the first direction. A region surrounded by the scanning lines 1 and the picture signal lines 2 is a pixel 3. The TFT substrate 100 is attached to the counter substrate 200 with a sealing material 50 of a first seal portion surrounding the display region 60 on the edge portions of the liquid crystal display panel and with a sealing material 50 of a second seal portion surrounding a hole portion 70 in the center. Both of a width w_s of the first seal portion and a width w_f of the second seal portion are about 0.8 mm.

The configurations of the first and the second seal portions are different. In the first seal portion, on the outermost part of the counter substrate 200, a bank-like spacer 20 is formed, and on the inner side of the bank-like spacer 20, the sealing material 50 is formed. The reason why the bank-like spacer 20 is formed on the outermost part is that in separating liquid crystal display panels out of a mother substrate by scribing, the sealing material on scribed regions is to be excluded.

On the other hand, in the second seal portion around the hole portion on the liquid crystal display panel 70, the sealing material 50 is formed up to the end portion, a wall-like spacer 10 is formed in a circular shape in the inside of the sealing material 50 so as to surround the hole portion. The configuration of the second seal portion is a feature of the embodiment of the present invention.

FIG. 2 is a cross-sectional view taken along line A-A in FIG. 1. On the left side of FIG. 2, the second seal portion that is the hole seal portion is shown. On the right side of FIG. 2, the first seal portion located on the end portion of the

4

display region. Components on the second seal portion side in FIG. 2 will be described. In FIG. 2, on the TFT substrate 100, a wiring layer 101, an organic passivation film 102, and an upper layer structure 103 are formed. A groove 1021 is formed on the organic passivation film 102 at the seal portion, and the organic passivation film 102 is discontinued. The groove 1021 is formed for preventing moisture from being externally entered to the display region through the organic passivation film 102. Note that, in the embodiment of the present invention, the groove 1021 of the organic passivation film 102 can be used for adjusting the width of the sealing material 50.

On the counter substrate 200, a black matrix 201, a color filter 202, an overcoat film 203, the wall-like spacer 10 that defines the gap between the TFT substrate 100 and the counter substrate 200 in the seal portion, a columnar spacer (a main spacer) 30 that defines the gap between the TFT substrate 100 and the counter substrate 200 in the display region, a sub-spacer 40, and other components. The black matrix 201 in the seal portion has a function as a light shielding film. A groove 2011 is formed on the black matrix 201 in the seal portion. The groove 2011 blocks moisture externally entered along the black matrix 201. In order not to leak light from the groove 2011 on the black matrix 201, a metal light shielding film 104 is formed at corresponding locations on the TFT substrate 100 side.

In FIG. 2, the TFT substrate 100 is attached to the counter substrate 200 with the sealing material 50.

The hole seal portion is characterized in that the sealing material 50 is formed up to the end portion. This configuration is provided for allowing the TFT substrate 100 and the counter substrate 200 to be processed at the same time in removing the hole portions using a drill with abrasive grains, for example, after the liquid crystal display panel is formed. In the inside of the sealing material 50, the wall-like spacer 10 is formed to define the gap between the TFT substrate 100 and the counter substrate 200. Forming the wall-like spacer 10 in the inside of the hole seal portion is a feature of the embodiment of the present invention. As illustrated in FIG. 1, the wall-like spacer 10 is formed around with no break.

In the hole seal portion, the sealing material contacts the liquid crystal. On the counter substrate 200 side of the display region, the black matrix 201 is formed. On the holes of the black matrix 201, a red filter 202R, a green filter 202G, and a blue filter 202B are disposed. The overcoat film 203 is formed covering the black matrix 201 and the color filter 202.

In the display region, the columnar spacer 30 is formed on the overcoat, film 203 to define the gap between the counter substrate 200 and the TFT substrate 100. The sub-spacer 40 has a function that prevents the gap between the TFT substrate 100 and the counter substrate 200 from being excessively small when a pressure is externally applied to the counter substrate 200 by a finger, for example, and a function that accelerates the velocity of returning the gap to the original state.

The right side of FIG. 2 is a cross-sectional view of the first seal portion formed on the edge portion of the liquid crystal display panel. The configurations of the TFT substrate 100 and the counter substrate 200 are similar to ones described on the left side of FIG. 2. On the end portion on the right side of FIG. 2, the bank-like spacer 20 is formed on the overcoat film 203 on the counter substrate 200. The bank-like spacer 20 is provided for easily separating the liquid crystal display panels in separating the liquid crystal display panels out of the mother substrate by applying an

impact after scribed. As illustrated in FIG. 1, the bank-like spacer **20** is formed around the display region with no break.

On the right side of FIG. 2, in the inside of the sealing material **50** of the first seal portion, a columnar spacer **30** is formed. The columnar spacer **30** is the same as the columnar spacer **30** in the display region. The configuration of the display region is the same on the right side and the left side of FIG. 2. The configuration of the seal portion is different between the first and the second seal portions.

In the following, the configuration of the hole seal portion, which is a feature of the embodiment of the present invention, will be described. FIG. 3 is a plan view of the configuration of the hole seal portion in FIG. 1, before the hole portion is removed. In FIG. 3, the sealing material **50** and a dummy sealing material **55** are concentrically formed. A linear sealing material **56** connecting the sealing material **50** to the dummy sealing material **55** is provided for drawing the sealing material with a single stroke with a dispenser. A dotted circle **51** in FIG. 3 is a mark indicating the start of drawing the sealing material with the dispenser.

A dotted circle **80** in the sealing material **50** in FIG. 3 is a cutting line. This portion is cut using a cutter with diamond abrasive grains, for example, to remove the circular portion. A feature is in that the cutting line **80** is present in the inside of the sealing material **50** for separating the TFT substrate **100** and the counter substrate **200** at the same time. The circular sealing material **55** on the inner side is provided for improving workability so that the materials on the end parts of the TFT substrate **100** and the counter substrate **200** are presented from falling apart.

In FIG. 3, the wall-like spacer **10** is formed in a circular shape on the display region **60** side of the cutting line **80**. The wall-like spacer **10** is formed on the overcoat film **203** on the counter substrate **200** side. On the outer side of the wall-like spacer **10**, the sealing material **50** is present. The region on the outer side of the sealing material **50** is the display region **60**. The display region **60** is filled with the liquid crystal.

FIG. 4 is a cross-sectional view taken along line B-B in FIG. 3. In FIG. 4, the region on the right side of the cutting line **80** is a region to be left as the liquid crystal display panel. The region on the left side of the cutting line **80** is the hole portion **70** to be removed. As illustrated in FIG. 4, the cutting line **80** is present in the region in which the sealing material **50** is formed. In the inside of the sealing material **50** on the liquid crystal side of the cutting line **80**, the wall-like spacer **10** is formed to define the gap between the TFT substrate **100** and the counter substrate **200** in the seal portion. The wall-like spacer **10** has a trapezoidal cross section. A width w_t of the upper base is about $10\ \mu\text{m}$. As illustrated in FIG. 3, the wall-like spacer **10** is formed around with no break. The width of the sealing material **50** after the hole portion is formed is about $0.8\ \text{mm}$. Thus, a plurality of wall-like spacers **10** can be formed as necessary. A liquid crystal **300** is sealed on the display region **60** side of the sealing material **50**. In the display region **60**, the columnar spacer **30** is formed for defining the gap between the TFT substrate **100** and the counter substrate **200**.

The region on the left side of the cutting line **80** is a dummy region. On the dummy region, the region between the sealing material **50** and the dummy sealing material **55** is a space. No spacers are necessary for the dummy sealing material **55**. However, the wall-like spacer **10** may be formed as depicted by a dotted line so that the dummy sealing material does not affect the gap between the substrates in the display region. The region on the left side of the dummy sealing material **55** is again a space.

In a manufacturing method for the liquid crystal display device, the sealing material **50** for attaching the TFT substrate **100** to the counter substrate **200** is formed on the edge portion of the counter substrate **200**, i.e., in the seal portion. After that, the liquid crystal is dropped in the reduced pressure. The TFT substrate **100** is attached to the counter substrate **200** in the reduced pressure, and then the substrates are returned in the atmospheric pressure. In this process, the sealing material, the columnar spacer, and the liquid crystal are compressed in the atmospheric pressure. As a result, the TFT substrate **100** and the counter substrate **200** are deformed. Depending on how to compress the sealing material, the columnar spacer, the liquid crystal, and other components at this time, the deformation of the substrates is varied. Thus, this causes a phenomenon in which the liquid crystal is entered between the sealing material **50** and the TFT substrate **100** or between the sealing material **50** and the counter substrate **200**.

FIGS. 5A to 5C are schematic diagrams for explaining this problem. FIG. 5A is a plan view of the counter substrate **200** corresponding to the region near a cross section taken along line C-C in FIG. 3. In FIG. 5A, the cutting line **80** is present in the sealing material. Note that, the cutting line is not marked in the sealing material. In the inside of the sealing material **50**, the columnar spacer **30** is formed for maintaining the gap between the TFT substrate **100** and the counter substrate **200** in the seal portion. The region on the left side of the sealing material **50** is the hole portion **70**.

On the other hand, the region on the right side of the sealing material **50** is the display region **60**. On the portion, the columnar spacer **30** is formed for defining the gap between the TFT substrate **100** and the counter substrate **200**. A liquid crystal drop **301** is dropped onto the region on the display region **60** side of the sealing material **50** in the reduced pressure. After that, the TFT substrate **100** is attached to the counter substrate **200** in the reduced pressure. After the attachment, the liquid crystal drop **301** is spread over the entire display region **60**. Note that, the liquid crystal drop **301** is dropped at a plurality of sites in the display region.

FIG. 5B is a cross-sectional view of the seal portion showing a state in which the TFT substrate **100** is attached to the counter substrate **200** in the reduced pressure. The gap between the counter substrate **200** and the TFT substrate **100** is maintained by the columnar spacer **30** in the display region and the columnar spacer **30** in the seal portion, and the gap between the TFT substrate **100** and the counter substrate **200** is constant. As described above, the reason why the attachment and dropping are performed in the reduced pressure is that no air is to be contained in the liquid crystal display panel.

FIG. 5C is a cross-sectional view of a region near the seal portion in the case in which the liquid crystal display panel in the state of FIG. 5B is returned in the atmosphere. When the panel is returned in the atmosphere, a pressure is applied to the TFT substrate **100** and the counter substrate **200**. Since the liquid crystal **300** is filled in the display region **60**, the gap between the TFT substrate **100** and the counter substrate **200** is not greatly changed. On the other hand, in the seal portion, the sealing material **50** is easily compressed by the atmosphere, because the volume of the sealing material **50** is small and the space is provided on the left side of the sealing material **50**. Although the columnar spacer **30** is formed in the seal portion as well, the columnar spacer **30** does not have repulsion force enough to resist the atmospheric pressure.

When the sealing material **50** is compressed, in the cross section of the liquid crystal display panel, a gap **h3** between the TFT substrate **100** and the counter substrate **200** in the seal portion is smaller than a gap **h4** in the display region, resulting in a barrel cross section. When the cross section is a barrel cross section, a phenomenon occurs in which the liquid crystal **300** is entered to the interface between the sealing material **50** and the TFT substrate **100**, or the interface between the sealing material **50** and the counter substrate **200**. In FIG. **5C**, arrows indicate this phenomenon. As described above, when the liquid crystal **300** is entered between the sealing material **50** and the substrates, the adhesive strength of the seal portion is decreased to degrade the reliability of the liquid crystal display panel. Moreover, the gap of the liquid crystal layer is affected near the sealing material, sometimes causing a degraded display quality.

FIGS. **6A** to **6C** are diagrams for explaining measures for this problem according to the embodiment of the present invention. FIG. **6A** is a plan view of the counter substrate **200** corresponding to a region near the cross section taken along line C-C in FIG. **3**. The state in FIG. **6A** is similar to the state in FIG. **5A** except that the wall-like spacer **10** is present in the inside of the sealing material **50**. The configuration in which the wall-like spacer **10** is present in the inside of the sealing material **50** is completely different from the configuration of the first seal portion on the outer edge of the liquid crystal display panel. Of course, a configuration like the configuration is not present in the display region as well.

FIG. **6B** is a cross-sectional view of a state in which the TFT substrate **100** is attached to the counter substrate **200** in the reduced pressure. In FIG. **6B**, the gap between the counter substrate **200** and the TFT substrate **100** is defined by the columnar spacer **30** in the display region **60**, and the gap is defined by the wall-like spacer **10** in the seal portion. The other configurations in FIG. **6B** are similar to ones described in FIG. **5B**.

FIG. **6C** is a cross-sectional view of a state in which the liquid crystal display panel illustrated in FIG. **6B** is returned in the atmosphere. FIG. **6C** is most different from FIG. **5C** in that a gap **h1** is maintained between the TFT substrate **100** and the counter substrate **200** in the seal portion with almost no influence of the atmospheric pressure on the gap. In other words, the wall-like spacer **10** is formed in the inside of the seal portion, and the strength of the wall-like spacer **10** against compression is much stronger than the strength of the columnar spacer **30**.

On the other hand, in the display region **60**, compressive stress is applied to the liquid crystal **300** by the atmospheric pressure. The columnar spacer **30** formed in the display region **60** has insufficient resistance to compressive force as well. Consequently, the cross-sectional topology of the liquid crystal display panel is a so-called deformed bobbin in which the gap **h2** between the TFT substrate **100** and the counter substrate **200** in the display region **60** is smaller than the gap **h1** in the seal portion.

In the case of this deformed bobbin, in the portion near the seal portion, the gap **h1** in the reduced pressure, which is the original gap, is maintained between the TFT substrate **100** and the counter substrate **200**. Thus, as a whole, the volume of accommodating the liquid crystal is greater than the volume in FIG. **5C**, and the force of entering the liquid crystal to the interface between the sealing material **50** and the TFT substrate **100**, or the interface between the sealing material **50** and the counter substrate **200** is smaller than the force illustrated in FIG. **5**.

The compressive force of the atmospheric pressure applied to the sealing material **50** also has a distribution in which the liquid crystal **300** is not easily entered between the sealing material **50** and the substrates. In other words, a pressure to compress-bond the substrates and the sealing material **50** is generated. Accordingly, a defect, in which the liquid crystal **300** is entered to the interface between the sealing material **50** and the TFT substrate **100** or the interface between the sealing material **50** and the counter substrate **200**, can be avoided. As described above, with the use of the embodiment of the present invention, the adhesive strength of the seal portion can be stably maintained, and the reliability of the liquid crystal display panel can be secured.

Another merit of according to the embodiment of the present invention is that the cross section of the liquid crystal display panel is a bobbin shape, i.e., the TFT substrate **100** or the counter substrate **200** is projected on the inner side. When this shape is formed, variations in the gap between the substrates of the liquid crystal display panel can be made smaller in the case in which a pressure is externally applied. In other words, the substrates are already deformed in the direction the same as the direction in which a pressure is external applied to the substrates. Thus, even though an external pressure is applied, the substrates are already in the state in which they are hardly further deformed. This is a great advantage in the case in which a touch panel function is imparted to the liquid crystal display panel, this.

The width **wf** of the sealing material **50** is about 0.8 mm, whereas the width of the wall-like spacer **10** is about 10 μ m. Thus, a plurality of wall-like spacers **10** can be disposed in the inside of the sealing material **50**. FIG. **7** shows this example. FIG. **7** is a plan view illustrating only a portion corresponding to the sealing material **50** in FIG. **3**. In FIG. **7**, the region on the inner side of the dotted cutting line **80** in the inside of the sealing material **50** is a portion removed with a glass cutter, for example.

Two wall-like spacers **10** are concentrically formed in the inside of the sealing material **50** on the display region **60** side of the cutting line **80**. The sealing material **50** is present between the two wall-like spacers **10**. The sealing material **50** is present on both sides of the two wall-like spacers **10**. The two wall-like spacers **10** are present. Thus, the gap in the seal portion can be more stably maintained, and the phenomenon, in which the liquid crystal is entered between the sealing material and the counter substrate or between the sealing material and the TFT substrate, can be prevented.

The number of sites, on which the wall-like spacer is provided, may be three or more as necessary. The wall-like spacer **10** can be simultaneously formed by the same process of photolithography with the same material when the columnar spacer is formed in the display region **60**. Thus, no process load is increased even though a plurality of wall-like spacers **10** is formed.

In the forming process of the seal portion, the wall-like spacer **10** is formed in advance in the seal portion of the counter substrate **200** by photolithography, and the sealing material **50** is disposed in the seal portion covering the wall-like spacer **10** with a dispenser. The liquid crystal is dropped onto the region on the display region **60** side of the sealing material **50**. After that, the TFT substrate **100** is attached to the counter substrate **200**. At this time, the sealing material **50** is pressed by the TFT substrate **100**, and spread in a predetermined width. In the spreading, the sealing material **50** is excluded from between the wall-like spacer **10** and the TFT substrate **100**.

However, in some cases, the sealing material **50** is not completely removed from between the wall-like spacer **10**

and the TFT substrate **100**, and the sealing material **50** is sometimes left. The sealing material left between the wall-like spacer **10** and the TFT substrate **100** is a factor to vary the gap between the counter substrate **200** and the TFT substrate **100**. Therefore, in order to stably maintain the gap between the TFT substrate **100** and the counter substrate **200**, no sealing material **50** is preferably left between the wall-like spacer **10** and the TFT substrate **100**.

FIG. **8** is a plan view of an example of the wall-like spacer **10** coping with this problem. FIG. **8** shows an example in which the planar shape of the wall-like spacer **10** is formed being bent in a saw shape. The wall-like spacer **10** may be bent in a wave shape. The sealing material **50** is formed covering the wall-like spacer **10** formed in the seal portion of the counter substrate **200** with a dispenser, and then the TFT substrate **100** is attached. The sealing material **50** is pressed by the TFT substrate **100**, and the sealing material **50** is removed from between the wall-like spacer **10** and the TFT substrate **100**. When the wall-like spacer **10** is formed in the shape as in FIG. **8**, oblique force is applied to the sealing material **50**, and the sealing material **50** is easily moved between the wall-like spacer **10** and the TFT substrate **100** as depicted by arrows in FIG. **8**. Accordingly, when the wall-like spacer **10** is formed in the shape as in FIG. **8**, the gap between the TFT substrate **100** and the counter substrate **200** in the seal portion can be further stabilized.

Moreover, in the wall-like spacer **10** as in FIG. **8**, since the area of the wall-like spacer **10** in a planer view is increased, the wall-like spacer **10** as in FIG. **8** also has an effect that can further increase the compressive stress of the wall-like spacer **10**. Accordingly, the gap between the TFT substrate **100** and the counter substrate **200** in the seal portion can be further stabilized.

As illustrated in FIG. **3**, the sealing material **50** has to be present on both sides of the wall-like spacer **10**, and the sealing material **50** has to be present also on both sides of the cutting line **80**. This means that when viewed in the cross section taken along line C-C in FIG. **3**, the position of the wall-like spacer **10** is often not matched with the center of the sealing material **50**. In the case in which the sealing material **50** in a large amount is formed on one side of the wall-like spacer **10**, the sealing material **50** insufficiently flows to the other side of the wall-like spacer **10** even though the sealing material **50** is pressed by the TFT substrate **100**. This causes the width of the sealing material to be unstable, resulting in a degraded reliability of the seal portion.

FIG. **9** is a plan view of the wall-like spacer **10** coping with this problem. In FIG. **9**, a first wall-like spacer **11** is non-consecutively formed at a first gap **g1**, and a second wall-like spacer **12** is non-consecutively formed at a second gap **g2**. Supposing that even in the case in which the sealing material **50** formed with a dispenser is formed in a large amount on one side of the wall-like spacers **11** and **12**, the sealing material **50** can flow through the gap between the wall-like spacers when pressed. Accordingly, the width of the sealing material **50** can be further stably formed.

In FIG. **9**, a width **w11** of the first wall-like spacer **11** is the same as a width **w12** of the second wall-like spacer **12**, and the gap **g1** between the first wall-like spacers **11** is the same as the gap **g2** between the second wall-like spacers **12**, which are $w11 > g1$ and $w12 > g2$. However, any dimensions are possible. Dimensions may be determined by taking into account of the elastic force (repulsion force) of the wall-like spacer and the flowability of the sealing material.

In FIG. **9**, the wall-like spacers are formed in two rows. However, the wall-like spacers may be formed in one row.

Also in this case, the width of the wall-like spacer is preferably greater than the gap between the wall-like spacers. For example, $w11 > g1$ is desirable. In FIG. **9**, the wall-like spacers are formed in two rows. However, the wall-like spacer can be formed in three rows or more.

FIG. **10** is a plan view of still another embodiment of a hole seal portion before the hole portion is formed. In FIG. **10**, the sealing material **50** and the wall-like spacer **10** are similar to ones in FIG. **3**. FIG. **10** is different from FIG. **3** in that the groove **1021** of the organic passivation film **102** in FIG. **2** is illustrated in FIG. **10**. The embodiment illustrated in FIG. **10** is characterized in that the width of a widened groove **1222** of the organic passivation film **102** is wider than the width of the other portions in a portion corresponding to a connecting portion **56** connecting the sealing material **50** to the dummy sealing material **55** in drawing the sealing material **50** with a single stroke.

In drawing the sealing material with a single stroke, the amount of the sealing material **50** is increased on a portion where the sealing materials **50** are overlapped with each other, causing the width of the sealing material **50** to be irregular on the portion. In FIG. **10**, in order to prevent this problem, the width of the groove **1021** of the organic passivation film **102** is increased on the portion where the sealing materials **50** are overlapped with each other, accommodating an excess amount of the sealing material **50** in the widened groove **1222** of the organic passivation film **102**. Thus, the width of the sealing material **50** can be stabilized.

The width of the widened groove **1222** of the organic passivation film is typically about $100\ \mu\text{m}$. However, in FIG. **10**, the width of the widened groove **1222** of the organic passivation film **102**, which is widened in the groove **1021** is about $200\ \mu\text{m}$. In FIG. **10**, a forming region **wg**, in which the widened groove **1021** of the organic passivation film **102** is formed, has a width almost the same as the width of the sealing material, which is about $0.8\ \text{mm}$. The organic passivation film **102** is formed to have a thickness as thick as a thickness of $2\ \text{to}\ 4\ \mu\text{m}$. Thus, the volume of accommodating the sealing material **50** in the portion of the widened groove **1222** of the organic passivation film **102** is considerably large. Note that, the width and forming region of the groove **1021** of the organic passivation film **102** only have to be adjusted being matched with the width, amount, and other parameters of the sealing material to be drawn with a single stroke.

FIG. **11** is a plan view of still another embodiment of the hole seal portion. FIG. **11** is different from FIG. **3** in that the sealing material **50** is also formed in the dummy region continuously to the seal portion. In other words, in FIG. **11**, the sealing material **50** is formed in a disk shape. The sealing material **50** in this shape can be formed by printing, for example. The sealing material **50** is formed in the shape as illustrated in FIG. **11**. Thus, the seal portion can be uniformly formed in the entire hole portion. In FIG. **11**, the region on the display region **60** side of the cutting line **80** is similar to the region in FIG. **3**, and the description is omitted.

In FIGS. **1** to **11**, the hole portion **70** is described to have a circular shape. However, the content described in FIGS. **1** to **11** is also applicable to the case in which the hole portion is in a polygon, not a circular shape, for example, which is a rectangular hole **70** as illustrated in FIG. **12**. FIG. **12** is a plan view of a hole seal portion after the dummy sealing material is cut. In FIG. **12**, the sealing material **50** is present at the end portion of the second seal portion so as to surround the hole seal portion. In the inside of the sealing material **50**, the wall-like spacer **10** is formed around with no break. For

11

the cross-sectional topology and other configurations of the hole seal portion, the configurations described in FIGS. 1 to 10 can be similarly used.

In the description above, the wall-like spacer is formed on the counter substrate side. However, the wall-like spacer may be formed on the TFT substrate side. In this case, taking into account of process loads, the columnar spacer is also desirably formed on the TFT substrate side. A configuration with no bank-like spacer 20 may be possible. In this case, a configuration may be possible in which the sealing material is provided to be terminated on the inner side of the end portion of the substrate, or a configuration may be possible in which the sealing material is left in the scribed region.

In the description above, as illustrated in FIG. 2, for example, the description is made on the premise of an In-Plane Switching (IPS) liquid crystal display device. However, the embodiment of the present invention is also applicable to liquid crystal display devices in other modes, such as twisted nematic (TN) and vertical alignment (VA) liquid crystal display devices.

What is claimed is:

1. A liquid crystal display device comprising: a TFT substrate having an organic passivation film and pixels in a display region; a counter substrate having a black matrix; and a first sealing material, wherein the TFT substrate and the counter substrate are fixed by the first sealing material, each of the TFT substrate and the counter substrate includes a penetrated hole, the penetrated hole is located inside of an outer shape of the TFT substrate and an outer shape of the counter substrate, the first sealing material surrounds the penetrated hole, the first sealing material is located between the display region and the penetrated hole, the black matrix has a first groove, the first groove surrounds the penetrated portion and overlaps the first sealing material, the organic passivation film has a second groove, the second groove surrounds the penetrated hole and overlaps the sealing material, and the first groove overlaps the second groove.
2. The liquid crystal display device of claim 1, wherein a width of the first groove is smaller than a width of the second groove.
3. The liquid crystal display device of claim 1, wherein the counter substrate further has a color filter, the color filter is directly on the black matrix, the color filter overlaps first sealing material, and the first groove is between a portion of the color filter and the penetrated hole.
4. The liquid crystal display device of claim 3, wherein the counter substrate further has overcoat film and a spacer,

12

the overcoat film covers the first groove and the color filter, the spacer is directly on the overcoat film, and the spacer overlaps the portion of the color filter and the first sealing material.

5. The liquid crystal display device of claim 4, wherein the spacer is a wall-like spacer, and the wall-like spacer surrounds the penetrated hole.

6. The liquid crystal display device of claim 5, wherein the TFT substrate further has a metal light shielding film, and the metal light shielding film overlaps the first groove.

7. The liquid crystal display device of claim 6, wherein the second groove has a first region and a second region, a first region overlaps the metal light shielding film, and a second region does not overlap the metal light shielding film.

8. A liquid crystal display device comprising: a TFT substrate having an organic passivation film and pixels in a display region; a counter substrate having a black matrix; and a first sealing material, wherein the TFT substrate and the counter substrate are fixed by the first sealing material,

each of the TFT substrate and the counter substrate includes a penetrated hole, the penetrated hole is located inside of an outer shape of the TFT substrate and an outer shape of the counter substrate,

the first sealing material surrounds the penetrated hole, the first sealing material is located between the display region and the penetrated hole, the black matrix has a first groove, the first groove surrounds the penetrated portion and overlaps the first sealing material, the black matrix has a first portion and a second portion, the first portion and the second portion overlap the first sealing material,

the first portion and the second portion are separated by the first groove, which is on the counter substrate, the first portion is between the penetrated hole and the first groove, the second portion is between the first groove and the display region, and the penetrated hole penetrates through both the TFT substrate and the counter substrate.

9. The display device of claim 8, further comprises a second sealing material, wherein the TFT substrate and the counter substrate are fixed by the second sealing material, the second sealing material formed along the outer shape of the TFT substrate or the outer shape of the counter substrate, and the second sealing material surrounds the display area.

* * * * *