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Display apparatus

Abstract

A display apparatus includes a substrate, an insulating layer, an alignment film, and a sealant. The insulating layer is disposed on the substrate and with a plurality of grooves. The alignment film is disposed on the insulating layer. The sealant is disposed on the alignment film. Wherein, the sealant overlaps at least a portion of the plurality of grooves. In a predetermined unit region, the side length of the predetermined unit region is a maximum width X of the sealant, and a total side length of the portions of the plurality of grooves located in the predetermined unit region is greater than 8 times of the maximum width X.

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Background/Summary

(1) This is a Continuation application of U.S. application Ser. No. 18/333,588 filed Jun. 13, 2023 (now patented as U.S. Pat. No. 12,055,819), which is a Continuation of U.S. application Ser. No. 18/060,082 filed Nov. 30, 2022 (now patented as U.S. Pat. No. 11,714,318, issued Aug. 1, 2023), which is a Continuation of U.S. application Ser. No. 17/585,739 filed Jan. 27, 2022 (now patented as U.S. Pat. No. 11,543,703, issued Jan. 3, 2023), which is a Continuation application of U.S.

application Ser. No. 17/153,948, filed Jan. 21, 2021 (now patented as U.S. Pat. No. 11,269,219, issued Mar. 8, 2022), which is a Continuation application of U.S. application Ser. No. 16/683,319, filed on Nov. 14, 2019 (now patented as U.S. Pat. No. 10,928,680, issued Feb. 23, 2021), which claims the benefit of People's Republic of China application Serial No. 201811509647.1, filed on Dec. 11, 2018, the subject matters of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

(1) The present disclosure relates in general to a display apparatus, and more particularly to a display apparatus having a liquid crystal panel.

Description of the Related Art

(2) A panel of a typical liquid crystal display apparatus includes two substrates and a liquid crystal layer disposed between these two substrates, and an alignment film in contact with the liquid crystal layer is further provided between the substrates and the liquid crystal layer. The substrates may have a display region and a frame region surrounding the display region, wherein a sealant is disposed in the frame region to adhere with these two substrates.

(3) As the development of the modern display technology, the frame region of display apparatuses is continually narrowed, the sealant originally disposed on the frame region may contact with the alignment films, due to lacking of space. However, the adhesion between the sealant and the alignment film may be so poor that may cause the sealant peeling from the substrate, and affect the quality of the liquid crystal display apparatus.

(4) Therefore, there is a need of providing an improved display apparatus to improve the adhesion of the sealant.

SUMMARY OF THE INVENTION

(5) One aspect of the present disclosure is related to a display apparatus, wherein the display apparatus includes a substrate, an insulating layer, an alignment film, and a sealant. The insulating layer is disposed on the substrate and with a plurality of grooves. The alignment film is disposed on the insulating layer. The sealant is disposed on the alignment film. The sealant overlaps at least a part of the plurality of grooves. In a predetermined unit region, the side length of the predetermined unit region is a maximum width X of the sealant, and a total groove side length of the plurality of grooves located in the predetermined unit region is greater than 8 times of the maximum width X.

(6) According to above embodiments of the present disclosure, a display apparatus is provided, wherein at least one insulating layer is provided on the substrate for forming a thin film transistor; and a plurality of grooves are formed in a portion of the insulating layer disposed in a frame region of the display apparatus. A sealant is then formed on the portion of the insulating layer disposed in the frame region to make the sealant at least overlapping a portion of the plurality of grooves. Thereby, the adhesion between the sealant and the substrates can be improved by the increasing the surface contacts between the sealant and insulating layer to prevent the sealant peeling from the substrate.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) The above and other aspects of the present disclosure will become better understood with regard to the following detailed description of the preferred but non-limiting embodiment(s). The following description is made with reference to the accompanying drawings.

(2) FIG. **1**A is a top view illustrating the structure of a display apparatus in accordance with one embodiment of the present disclosure.

(3) FIG. **1**B is a cross-sectional view illustrating a partial structural of the display apparatus taken along a cutting line G in FIG. **1**A.

(4) FIG. **2** is a top view illustrating the structure of an insulating layer in accordance with one embodiment of the present disclosure.
(5) FIG. **3** is a top view illustrating a partial structure of the display apparatus as depicted in FIG. **1**A.
(6) FIG. **4** is a top enlarged view illustrating a partial structure of a display apparatus in accordance with another embodiment of the present disclosure.
(7) FIG. **5** is diagram illustrating the relationship between the width of a sealant and its peel strength.
(8) FIGS. **6**A-**6**B are cross-sectional views illustrating partial fabricating structures of an alignment film according to one embodiment of the present disclosure.
(9) FIG. **7**A is a cross-sectional view illustrating a partial structure of a display apparatus in accordance with yet another embodiment of the present disclosure.
(10) FIG. **7**B are top views illustrating the partial structures of an insulating layer and another insulating layer (as depicted in FIG. **7**A) and the assembly structure thereof in accordance with one embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE INVENTION

(11) Present disclosure provides a display apparatus to solve the problems that a sealant is easily peeled off from the transparent substrate of a liquid crystal panel. In order to make the objects, features and advantages of the present invention more apparent, several preferred embodiments are described below in detail with reference to the accompanying drawings.
(12) It is to be noted that the following descriptions of preferred embodiments of this disclosure are presented herein for purpose of illustration and description only not for limiting the scope of the invention. It is not intended to be exhaustive or to be limited to the precise form disclosed. Also, it is also important to point out that there may be other features, elements, steps and parameters for implementing the embodiments of the present disclosure which are not specifically illustrated.
(13) Furthermore, the use of ordinal numbers such as “first”, “second”, and the like, as used in the specification and the claims are just used to modify the elements in the claims. It neither mean that it has any previous ordinal number on behalf of the requested element, nor does it represent the sequence order of one request element and another request element. These ordinal numbers are only used for enabling a requested element with a certain name for distinguishing another requested element having the same name. In addition, the positions mentioned in the specification and claims, such as “above”, “upper”, “on”, “below”, “lower” or “under”, may either mean that the two elements are in direct contact, or may refer to that the two components are not in direct contact.
(14) Those skilled in the art will be able to make equal modifications and variations without departing from the spirit and scope of the disclosure. In the different embodiments and the drawings, the same elements will be denoted by the same reference numbers.
(15) FIG. **1**A is a top view illustrating the structure of a display apparatus **100** in accordance with one embodiment of the present disclosure. FIG. **1**B is a cross-sectional view illustrating a partial structural of the display apparatus **100** taken along a cutting line G in FIG. **1**A. As shown in FIG. **1**A, the display apparatus **100** has a display region **101**, a frame region **102** and a bonding region **103**. The display region **101** includes a plurality of pixels **101***a* for displaying an image. The frame region **102** is disposed at the periphery of the display region **101** and is adjacent to the display region **101**. The bonding region **103** is disposed out of one side or more than one sides of the frame region **102**. In the present embodiment, the bonding region **103** can be disposed out of one single side of the frame region **102**, and is not limited thereto. The bonding region **103** can be used to provide pins and pads (not shown) to be bonded to an external connection line (not shown).
(16) In some embodiments of the present disclosure, the display apparatus **100** can be a liquid crystal panel. The display apparatus **100** may include a substrate **104**, a substrate **105**, a plurality of thin film transistors **106**, an alignment film **107**, a liquid crystal layer **108**, a sealant **109**, an insulating layer **116**, and an insulating layer **110**. The substrate **105** is disposed on the substrate

104, and the liquid crystal layer **108** is disposed between the substrate **104** and the substrate **105**. In order to guide the liquid crystal molecules in the liquid crystal layer **108** aligning in the same direction, the alignment film **107** can be disposed on the substrate **104** and adjacent to the liquid crystal layer **108** to make the liquid crystal molecules having a predetermined pretilt angle. The insulating layer **116** can be disposed between the alignment film **107** and the thin film transistors **106**, and the insulating layer **116** may be a planarization layer. The display apparatus **100** may further include a light shielding layer **120** disposed between the substrate **105** and the liquid crystal layer **108** covering the frame region **102**; and a portion of the light shielding layer **120** is disposed in the display region **101**. Wherein a pixel light-emitting region **101***a* may be a light-transmitting region defined by the portion of the light shielding layer **120** disposed in the display region **101** (for example, the light shielding layer **120** may be a black matrix, a metal layer or a filter layer overlap). Alternatively, the pixel light-emitting region **101***a* may be a light-emitting region of an organic light-emitting layer in an organic light-emitting diode. The pixel light-emitting region **101***a* may also be a light emitting region in an inorganic light-emitting diode. In the pixel light-emitting region **101***a*, the plural thin film transistors **106** can be electrically connected to the pixel electrodes (not shown) for controlling the on/off state of each pixel.
(17) The substrate **104** and the substrate **105** may be a rigid substrate or a flexible substrate. The materials of the substrate **104** and the substrate **105** may include glass, polyimide (PI), polyethylene terephthalate (PET) or any other light-transmitting plate or film material suitable for forming a substrate, but it is not limited thereto. In addition, although the display apparatus **100** illustrated in the embodiment is rectangular, the shape thereof is not limited thereto. The shape of the display apparatus **100** may be triangular, prismatic, trapezoidal, wedge-shaped, other polygonal or irregular with arc edges. The shapes of the substrate **104** and the substrate **105** may also be different, and the dimensions of these two substrates may not be strictly limited. The dimensions of the substrate **104** and the substrate **105** can be substantially the same or different.
(18) Referring to FIG. **1**A, in the top view, the alignment film **107** may cover the display region **101**, the frame region **102**, or the bonding region **103**, either partially or a whole region thereof, which is not limited thereto. In the present embodiment, the alignment film **107** covers the entire display region **101** and the entire frame region **102**. In some other embodiments of the present disclosure, the alignment film **107** covers the entire display region **101** and a portion of the frame region **102**. The alignment film **107** may be a PI alignment film or a polymer-stabilized alignment (PSA) film, but the material thereof is not limited thereto.
(19) Referring to FIGS. **1**A and **1**B, a plurality of thin film transistors **106** (only one of which is shown as a representative) are formed on the substrate **104**, wherein the thin film transistors **106** can be selectively disposed in the display region **101** or the frame region **102** of the display apparatus **100**. The thin film transistor **106** further includes a drain **106***a*, a source **106***b*, a gate **106***c*, and an active layer **106***d*. The gate electrode **106***c* is disposed on the substrate **104**; the active layer **106***d* is disposed over the gate **106***c*; and the drain **106***a* and the source **106***b* are disposed adjacent to the active layer **106***d*, partially covering the two sides of the active layer **106***d*, and separated from each other respectively. The drain **106***a*, the source **106***b*, the gate **106***c*, and the active layer **106***d* may be formed by deposition including chemical vapor deposition (CVD) or physical vapor deposition (PVD), evaporation, sputtering or other suitable methods, but not limited thereto. The thin film transistor **106** is not limited to be a bottom gate (BG) thin film transistor, a top gate (TG) thin film transistor, or a combination of these two.
(20) There may be at least one or more insulating layers disposed between the alignment film **107** and the substrate **104**, and the insulating layers are formed on the substrate **104** by CVD or PVD technology for isolating different electrodes. These insulating layers may be formed of a material which can be either an inorganic material or an organic material, and the material may be, for example, silicon nitride (SiNx), silicon oxide (SiOx) or polyfluoroalkoxy (PPA), but is not limited thereto. In the present embodiment (in the cross-sectional view of FIG. **1**B), one of the insulating

layers, such as the insulating layer **110**, is disposed between the source **106***b* and the gate **106***c* and may serve as the gate dielectric layer of the thin film transistor **106**, but not limited thereto. In some other embodiments, the insulating layer **110** may be disposed on the drain **106***a* and the source **106***b* serving as a protective layer thereof, serving as one of organic insulating layers (PFA), or serving as one of the insulating layers disposed between the semiconductor active layer **106***d* and the substrate **104**. In the top view, the insulating layer **110** may cover the display region **101**, the frame region **102**, or the bonding region **103**, either partially or a whole region thereof, which is not limited thereto. In the present embodiment, the insulating layer **110** covers the entire display region **101** and the entire frame region **102**.

(21) The portion of the insulating layer **110** disposed in the frame region **102** can be formed by a semiconductor process including steps of transferring the pattern of a reticle onto the substrate **104** by photolithography, and then removing the portion of the insulating layer **110** that is not protected by the photoresist, whereby the portion of the insulating layer **110** disposed in the frame region **102** has a plurality of grooves **111** and a plurality of protrusions **110***a*. The protrusions **110***a* are defined by the sidewalls **111**S and **111**S′ of two adjacent grooves **111** and the top portion **110***b* of the protrusions **110***a*. In the present embodiment, one of the protrusions **110***a* may be a hill-like protrusion (such as a trapezoid protrusion) having the sidewall **111**S or **111**S′ extending outward. In some other embodiments, the shape of the top portion **110***b* of the protrusions **110***a* and the sidewall **111**S or **111**S′ may be at least partially curved, but is not limited thereto, wherein the material of the protrusions **110***a* is the same as that of the insulating layer **110**. In some embodiments of the present disclosure, the plurality of grooves **111** may be a plurality of continuous or discontinuous grooves, which may be, for example, elongated grooves.

(22) Because the plurality of grooves **111** and the plurality of protrusions **110***a* may cause the topography of the insulating layer **110** uneven, the material for forming the alignment film **107**, prior to curing, may flow along the uneven topography and partially accommodated in the grooves **111**, whereby a portions of the alignment film **107** may be formed in the grooves **111**, and the top surface **107***a* of the portion of the alignment film **107** accommodated in the grooves **111** may not extend beyond the top portion **110***b* of the protrusions **110***a*. Such that a partial of the sidewalls of the protrusions **110***a* (i.e. the sidewalls **111**S and **111**S′ of the grooves **111**) and the top portion **110***b* of the protrusions **110***a* may be (not limited to) contact with the alignment film **107**, but it is not limited thereto. In the present embodiment, the top portion **110***b* of the protrusions **110***a* does not be contact with the alignment film **107**, the sidewalls **111**S and **111**S′ of the grooves **111** can be at least partially contact with the alignment film **107**.

(23) As shown in FIG. **1**A, the sealant **109** is disposed in the frame region **102** and along the periphery of the display region **101**. The shape or position of the sealant **109** formed in the frame region **102** may not be limited and can be varied according to the design requirements of the display apparatus **100**. In the present embodiment, the sealant **109** can be a rectangular line in the top view, and the edge **109***a* of the sealant **109** can align the outer edge **102***a* of the frame region **102**. In some other embodiments, in top view, the sealant **109** may be an irregular curve, and the edge **109***a* of the sealant **109** does not align the outer edge **102***a* of the frame region **102**. It should be noted that the sealant **109** is not an absolutely equal width line in top view, and may have a maximum width X within a sampling region. In the present embodiment, the sealant **109** has a width ranging from 400 μm to 1500 μm and a maximum width X about 15000 μm within the sampling region. In some other embodiments, the sealant **109** has a width ranging from 450 μm to 850 μm. As shown in FIG. **1**B, the portion of the sealant **109** disposed in the frame region **102** can be attached to the substrate **104** by selectively contacting the top surface **107***a* of the alignment film **107**, the sidewalls **111**S and **111**S′ of the groove **111** and the top portion **110***b* of the protrusions **110***a*. Because the poor adhesion between the sealant **109** and the alignment film **107**, therefore, increasing, the total area of the contact surface formed between the sealant **109** and the top surface **110***a* of the protrusion **110***a* by the design of the groove **111**. The adhesion between the sealant **109**

and the substrate **104** can be improved.

(24) Referring to FIG. **2**, the insulating layer **110** has a plurality of grooves **111**, and each of the grooves **111** may optionally further include a sub-groove **111**A, a sub-groove **111**B, a sub-groove **111**C, and a sub-groove **111**D. The long axis of the sub-groove **111**A extends in the direction L**1** (for example, the Y direction); the long axis of the sub-groove **111**B extends in the direction L**2** (for example, the Y direction); the long axis of the sub-groove **111**C extends in the direction L**3** (for example: The X direction); the long axis of the sub-groove **111**D extends in the direction L**4** (for example, the X direction); and the sub-groove **111**C or the sub-groove **111**D may connect the sub-groove **111**A and the sub-groove **111**B. In other words, the sub-groove **111**C and the sub-groove **111**D are two lateral trenches other than the portions overlapping with the sub-groove **111**A and the sub-groove **111**B. The direction L**3** (X) and the direction L**4** (X) are different from the direction L**1** (Y), and the direction L**3** and the direction L**4** are different from the direction L**2** (Y). The direction L**1** and the direction L**2** may be parallel or non-parallel with each other, and may form an angle φ between each other, wherein the angle q is less than 180°. In the present specification, the grooves **111** may be formed at the outer edge **102***a* of the frame region **102**, and the grooves **111** may be parallel or non-parallel to each other, and are not limited thereto. The distance between the sidewalls **111**S and **111**S′ of two adjacent grooves **111** may be represented as P (FIG. **2**) that is the width of the top portion **110***b* of the protrusion **110***a*. The distance P between two adjacent grooves **111** may be equal or non-equal in width, and is not limited thereto. In another embodiment, the sidewall **111**S of the grooves **111** may have some micro-roughness which can prevent the material for forming the alignment film **107** reflowing, after it flows into the grooves **111**, so that less material of the alignment film **107** may be remained on the top portion **110***b* of the protrusion **110***a*. This can increase the contact area between the sealant **109** and the insulating layer **110** to improve the adhesion between the sealant **109** and the insulating layer **110**. When the sealant **109** is in contact with the sidewall of the insulating layer **110** having the micro-roughness (the sidewall **111**S of the grooves **111**), the adhesion between the sealant **109** and the insulating layer **110** can also be improved. In another embodiment, the sidewall **111**S of the grooves **111** may have a slight wave shape or a curved edge when viewed from a top view. When the substrate **109** and the aligned substrates **104** and **105** are squeezed to apply stress to the sealant **109**, the wave or curved shaped sidewall **111**S of the grooves **111** can contribute the support force in different directions to reduce the risk that the sealant **109** may be peeled off from the substrate **104**.

(25) FIG. **2** is a top view illustrating the structure of an insulating layer **110** disposed in the frame region **102**. In one embodiment of the present disclosure, the direction L**1** may be parallel to the direction L**2**; the direction L**3** may be perpendicular to the direction L**1** or the direction L**4** may be perpendicular to the direction L**1**. In another embodiment, the direction L**1** and the direction L**2** are not parallel with each other, instead forming an angle q less than 180°. More notably, the grooves **111** formed in the insulating layer **110** may selectively further include a groove **111**E between two adjacent sub-grooves (such as the sub-grooves **111**A and **111**B), but not connected with the sub-groove s **111**A and **111**B. In the present embodiment, the sub-grooves **111**E not only is disposed between the two adjacent sub-grooves **111**A and **111**B, but also disposed between the two adjacent sub-grooves **111**C and **111**D. The sub-groove **111**E, in top view, may be shaped as a rectangular, a circular, an elliptical or other irregular shape, and is not limited thereto. The sub-groove **111**A, the sub-groove **111**B, the sub-groove **111**C, the sub-groove **111**D, and the sub-groove **111**E may form a plurality of patterns having the same size. For example, the area of each pattern may be the same, but each of which may have different total side length; or the area of these patterns may be different, but each of which may have the same total side length. These patterns may be selectively arranged in a regular manner, and is not limited thereto. In some other embodiments, the sub-groove **111**A, the sub-groove **111**B, the sub-groove **111**C, the sub-groove **111**D and the sub-groove **111**E may have different sizes according to the design requirements; the shape thereof may be not limited to a rectangle; at least one of these patterns may have a circular or arc edge. In yet another

embodiment, not every groove **111** includes one sub-groove **111**A, one sub-groove **111**B, one sub-groove **111**C, one sub-groove **111**D and one sub-groove **111**E. The sub-grooves **111**C, the sub-grooves **111**D and the sub-grooves **111**E may have different distribution conditions and sizes according to the design requirements, and are not limited thereto.
(26) FIG. **3** is a top view illustrating a partial structure (within a sampling region defined by the dotted line AA) of the display apparatus **100** as depicted in FIG. **1**A. Within the sampling region (also referred to as a unit region U), the projection pattern **109***c* formed by projecting the profile of the sealant **109** onto the substrate **104** has a maximum width X from the edge **109***a* staying away from the display region **101** to another edge **109***b* getting close to the display area **101**, wherein theses edges **109***a* and **109***b* serve as two opposite sides of the square unit region U with a side length of maximum width X. The square unit region U overlaps at least part of the grooves **111** and a portion of the sealant projection pattern **109***c*, and the area of the grooves **111** overlapping with the sealant **109** within the square unit region U is greater than or equal to 50% the area of the square unit region U. The total side length of the portions of the grooves **111** that are located in the unit region U can be referred to as the total groove side length, and the total groove side length is greater than 8 times the maximum width X (>8X). In the present embodiment, since the sealant **109** has less width variation, thus any portion of the sealant **109** disposed in the frame region **102** can be sampled to serve as the square unit region U. For example, one side of the sealant **109** aligning the outer edge **102***a* of the frame region **102** can be referred to a reference side of the square unit region U; and a distance counted from the reference side and getting close to the display region **101** about 1 cm or 2 cm can be referred to as the maximum width X; thereby the square unit region U can be figured out by using the reference side and the maximum width X.
(27) Referring to FIGS. **3** and **4**, the method for calculating the total groove side length in the unit region U is provided as follows: FIG. **4** is a top enlarged view illustrating a partial structure of the display apparatus **100** in accordance with another embodiment of the present disclosure. In the present embodiment, as shown in FIG. **4**, the portion of the grooves **111** that are located in the unit region U overlaps with the sealant projection pattern **109***c*, and the sides of the grooves **111** overlapping with the sealant projection pattern **109***c* forms six square patterns of side length k (the total side length of each square pattern is 4k) and six incomplete squares (the total side length of each incomplete square pattern is k/2+k+k/2=2k). The total groove side length is 6×4k+6×2k=36k that is greater than 8 times the maximum width X of the sealant **109**, wherein the units of k and X are the same. The total groove side length in the unit region U can be expressed by the formula (1):
$36k>8X \qquad (1).$
(28) The aforementioned “incomplete (square)” means the (square) pattern that formed by the sides of the grooves **111** is not completely overlapping with the sealant projection pattern **109***c*, when calculating the total groove length in the unit region U.
(29) Referring to FIG. **3** again, the frame region **102** is disposed adjacent to the display region **101**; the plurality of grooves **111** are formed in the portion of the insulating layer **110** that is disposed in the frame region **102**; the sealant **109** has a maximum width X between the two edges **109***a* and **109***b* thereof; and the sealant **109** covers portions of the grooves **111**.
(30) The display apparatus **100** further may optionally include at least one gate on panel (GOP) **115** disposed in the frame region **102** between the edge **109***b* of the sealant **109** and the display region **101**. GOP **115** includes at least one thin film transistor (not shown). It is noted that at least one of the thin film transistors in the GOP **115** may have a size greater than that at least one of the thin film transistor **106** disposed in the display region **101**. In the present embodiment, the GOP **115** has a width ranging from 400 μm to 800 μm.
(31) The grooves **111** are typically disposed adjacent the outer edge **102***a* of the frame region **102**. Since the cutting line **114** is aligned with the outer edge **102***a* of the frame region **102**, thus the portion of the frame region **102** out of the outer edge **102***a* of the frame region **102** could be cut off and does not appear in the final state of the display apparatus **100** after the cutting process.

However, portions of the grooves **111** close to the cutting line **114** may likely be cut off by the cutting process, due to the process tolerance in the cutting process. In order to ensure that there are grooves **111** still remained in the frame region **102** after the cutting process, it is necessary to form at least three grooves **111** in the insulating layer **110** to avoid the problem of insufficient number of the grooves **111** in the final product, due to process tolerances, which may adversely affecting the adhesion of sealant.

(32) In the present embodiment, the edge **109***a* of the sealant **109** is aligned with the outer edge **102***a* of the frame region **102**, and is not limited thereto. In some other embodiments, the edges **109***a* of the sealant **109** may not be alignment with the outer edge **102***a* of the frame region **102**. In the present embodiment, the distance from the cutting line **114** to the inner edge **102***b* of the frame area **102** may range from 800 to 1000 μm (micrometers), For example, the distance may be about 900 μm.

(33) FIG. **5** is diagram illustrating the relationship between the width of a sealant **109** and the peel strength measured by an adhesion test conducted on the substrate **104** including the grooves **111** as depicted in FIG. **2** and the sealant **109**. According to FIG. **5**, it can be determined that when the width of the sealant **109** is small (for example, less than 500 μm), there is no difference in the adhesion strength between the sealant **109** and the substrate **104** having the different number (**3**, **4** or **5**) of the grooves **111**. However, as the width of the sealant **109** is gradually increased (for example, 600 μm), the adhesive strength between the sealant **109** and the substrate **104** having more than three grooves **111** is stronger than that adhesive strength between the sealant **109** and the substrate **104** merely having three grooves **111**. Therefore, the present disclosure selects the substrate **104** having more than three grooves **111** as the design trend of the display device **100**.

(34) FIGS. **6**A-**6**B are cross-sectional views illustrating partial fabricating structures of the alignment film **107** according to one embodiment of the present disclosure. Referring to FIG. **6**A, in the cross-sectional view, each one of the grooves **111** disposed in the frame region **102** has an opening width S which is the distance between the top portions **110***b* of the two adjacent protrusions **110***a*. If the opening width S is too large, on one hand, the total number of the grooves **111** may be sacrificed, and sufficient contact area may not be provided between the insulating layer **110** and the sealant **109**. On the other hand, if the opening width S is too small, the space of the grooves **111** may be insufficient to accommodate the alignment film **107**. Such that, the opening width S needs to be limited, for the purpose of not affecting the quality of the display apparatus **100**.

(35) FIG. **6**A schematically shows the initial state when the alignment film **107** is formed over the substrate **104**, wherein a portion of the alignment film **107** is formed on the top portions **110***b* of the protrusions **110***a*. Since the material for forming the alignment film **107** has fluidity, thus the material for forming the alignment film **107** may flow along the topography of the frame region **102** and reflow into the groove **111**, prior to curing. As shown in FIG. **6**B, the top portions **110***b* of the protrusions **110***a* has no or less residual material of the alignment film **107**; and the top surface **107***a* of the alignment film **107** in the grooves **111** approach the top portions **110***b* of the protrusions **110***a*. However, the top surface **107***a* does not exceed the top portions **110***b*. In order to preventing the top surface **107***a* of the portion of the alignment film **107** accommodated in the grooves **111** to exceed beyond the top portions **110***b* of the protrusions **110***a*, the area of the grooves **111** needs to be greater than or equal to the area of the material of the alignment film **107** originally accommodated in the grooves **111** plus the area of the material subsequent reflowing into the grooves **111**. This conforms to the following formula (2):

(36) $(S+(S-2d\times \mathrm{Cot}\theta))\times d/2 \geqq P\times t+S\times t \quad (2)$

(37) Wherein, S represents the opening width of the grooves **111**; P represents the width of the top portions **110***b* of the protrusions **110***a*; t represents the height of the portion of the alignment film **107** disposed on the display region **101**. In the present embodiment, t may represent the thickness

of the portion of the alignment film **107** disposed in the display region **101** corresponding to the pixel light-emitting region **101***a*. The thickness of the portion of the alignment film **107** may range from 0.05 μm (ie, 500 Å) to 0.15 μm or from 0.06 μm to 0.11 μm, which is not limited thereto. Since the thickness of the alignment film **107** varies depending on the position of measurement, thus, in one embodiment of the present disclosure, an average value of a three-point measurement performed on three locations in the display region **101** can be taken to estimate the thickness of the alignment film **107** corresponding to the pixel light-emitting region **101***a*, wherein d represents the height of the groove **111**, and the units of S, P, t and d are the same. In the present embodiment, d may range from 0.3 μm to 1 μm, which is not limited thereto. **0** represents the angle formed by the sidewall **111**S of the groove **111** and the bottom **110**Q of the protrusion **110***a*, wherein θ may range from 15° to 75°. In some embodiments of the present disclosure, θ ranges from 20° to 70°, which is not limited thereto. Formula (3) can be obtained by converting the formula as follows:

(38) $S \geqq (P \times t + d^2 \times \mathrm{Cot}\theta) / (d - t)$ (3)

(39) In the present embodiment, the width P is about 20 μm; the height t is about 0.1 μm; the height d is about 0.5 μm; the angleθ is about 45°; and the opening width S≥5.625 μm.

(40) In addition, when the unit region U defined by the maximum width X of the sealant **109** includes only three grooves **111**, the total width **3**S of the openings (each of a widths S) of these three grooves **111** must be smaller than the maximum width X of the sealant **109**, this can be represented by the formula (4):

(41) $3S < X$ (4)

(42) Therefore, combining the formula (3) with the formula (4) yields the formula (5), and the opening width S of the groove **111** needs to satisfy the formula (5):

(43) $1/3X > S \geqq (P \times t + d^2 \times \mathrm{Cot}\theta) / (d - t)$ (5)

(44) It should be noted that when the width P of the top portions **110***b* of the protrusions **110***a* is too large, the material for forming the alignment film **107** cannot reflow easily into the grooves **111**, so that a large amount of residual material of the alignment film **107** may remain on the top portion **110***b*, and this may adversely affect the adhesion between the sealant **109** and the substrate **104**. On the other hand, when the width P of the top portions **110***b* of the protrusions **110***a* is too small, the contact area formed between the top portions **110***b* of the protrusions **110***a* and the sealant **109** may be insufficient, that also cannot increase the adhesion between the sealant **109** and the substrate **104**. Therefore, those skilled in the art can obtain the formula (6) according to formula (2):

(45) $P \leqq [S(d - t) - d^2 \mathrm{Cot}\theta] / t$ (6)

(46) The range of the width P of the top portions **110***b* of the protrusions **110***a* can be obtained from this formula (6). In the present embodiment, the opening width S is about 3.5 μm; the height t is about 0.1 μm; the height d is about 0.5 μm; the angle θ is about 45°; and the width P≤11.5 μm.

(47) Referring to FIGS. **7**A and **7**B, FIG. **7**A is a cross-sectional view illustrating a partial structure of a display apparatus **100** in accordance with yet another embodiment of the present disclosure; and FIG. **7**B are top views illustrating the partial structures of the assembly structure of the insulating layer **110** and another insulating layer **112** (as depicted in FIG. **7**A) in accordance with one embodiment of the present disclosure. In the present embodiment, the structure of the display apparatus **100** as depicted in FIG. **7**A is substantially similar to that of FIG. **1**B except that the display apparatus **100** depicted in FIG. **7**A further includes an insulating layer **112** formed on the insulating layer **110** by CVD or PVD technology. The portion of the insulating layer **112** disposed in the display region **101** may cover at least a portion of the drain **106***a*, the active layer **106***d*, the source **106***b*, and the insulating layer **110**. The insulating layer **112** may serve as a passivation layer of the thin film transistor **106**, which is not limited thereto. In some other embodiments of the present disclosure, the insulating layer **112** can serve as a planarization layer or the like. The material of the insulating layer **112** may include, for example, silicon nitride (SiNx), silicon oxide

(SiOx), or an organic material.

(48) Referring to FIG. **7**A and FIG. **1**A simultaneously, the insulating layer **112** (at a top view angle) may cover the display region **101**, the frame region **102**, or the bonding region **103**, either partially or a whole region thereof, which is not limited thereto. In the present embodiment, the insulating layer **112** and the insulating layer **110** may cover at least a portion of the display region **101** and at least a portion of the frame region **102**. Referring to FIG. **7**A, the portion of the insulating layer **112** disposed in the frame region **102** may have a plurality of grooves **113** and a plurality of protrusions **113***a* that are formed in the same manner as the aforementioned grooves **111**, thus the materials and the method for manufacturing the same will not be redundantly described here. The protrusions **113***a* are defined by the sidewalls **113**S and **113**S′ and the top portions **113***b* of two adjacent grooves **113**. In the present embodiment, one of the protrusions **113***a* may be a hill-like protrusion (such as a trapezoid protrusion) having the sidewall **113**S or **113**S′ extending outward. In some other embodiments of the present disclosure, the portion of the trapezoid protrusion disposed between the top portion **113***b* of the protrusions **113***a* and the sidewalls **113**S or **113**S′ may be at least partially curved, and is not limited thereto. The material of the protrusions **113***a* is the same as that of the insulating layer **112**. In addition, each of the grooves **113** corresponds to one of the grooves **111** and has an opening width S**22**. The opening width S**22** is a distance between the top portions **113***b* of the two adjacent protrusions **113***a*, the opening width S**22** may be the same as or different from the width S of the groove **111**, and is not limited thereto.

(49) It should be noted that, in the top view, at least one portion of the grooves **113** do not overlap with the corresponding grooves **111**, and at least one portion of the grooves **111** do not overlap with the corresponding grooves **113**. As shown in FIG. **7**B, in the same region, the projection pattern B that formed by projecting the profiles of the plurality of grooves **113** onto the substrate **104** overlaps with the projection pattern A formed by projecting the profiles of the plurality of grooves **111** onto the substrate **104**. In the projection pattern C (obtained by the overlapping of the projection pattern A and the projection B), the sidewalls **111**S′ of the grooves **111** is not aligned with and not parallel to the sidewalls **113**S of the grooves **113**. For example, in the present embodiment, the plurality of grooves **111** formed in the insulating layer **110** may include a plurality of strip-shaped (e.g. rectangular) elongated grooves; and the plurality of grooves **113** formed in the insulating layer **112** may include multiple elongated grooves having irregular shapes, such as (but not limited to) S-shaped, zigzag, twist-shaped or other irregular patterned grooves; but which is not limited thereto.

(50) Moreover, the shape, size, and stacking order of the aforementioned grooves **111** and grooves **113** are not limited thereto. For example, in another embodiment of the present disclosure, the plurality of grooves **113** formed in the insulating layer **112** may include a plurality of strip-shaped elongated rectangular grooves; and the plurality of grooves **111** formed in the insulating layer **110** may include a plurality of irregular shaped elongated grooves.

(51) As shown in FIG. **7**A, since the sealant **109** may extend into the grooves **111** and the grooves **113**, thus the contact area formed between the sealant **109** and the insulating layers **110** and **112** can be increased, so as to improve the adhesion between the sealant **109** and the substrate **104**. In addition, referring to FIG. **7**B, in the range of sampling, the total groove side length in the unit region U is calculated by the following manners: the total side length of the portion of the grooves **111** disposed in the unit region U plus the total side length of the portion of the groove **113** disposed in the unit region U; and any side or edge of the grooves **111** and **113** (disposed in the unit region U) that can contribute the adhesion of the sealant **109** should be included in the calculation of the total groove side length.

(52) In detail, as shown in FIG. **7**B, for example, there are three grooves **111** partially located in the unit region U that is defined/sampled in the projection pattern C. Each of the grooves **111** has two sides extending for a length r in the unit region U along the long axis L**71**. The total side length of the portions of the side of the three grooves **111** located in the unit region U is 3×2r. There are three

grooves **113** located in the unit area U. Each of the grooves **113** has two sides extending for a length w in the unit region U along the long axis L**72**. The total side length of the portions of the side of the three grooves **113** located in the unit area U is 3×2w. The total groove length of the portions of grooves **111** and the grooves **113** located in the unit area U is 3×(2r+2w), wherein the unit of r and w is the same.

(53) It should be noted that although FIG. **7**A and FIG. **7**B only show two layers of partially overlapping insulating layer **110** and insulating layer **112**, in other embodiments of the present disclosure, the display apparatus **100** may include more similar structures of insulating layers. The pattern and stacking manner of the grooves are not limited. Those skilled in the art can vary the number of insulating layers and the pattern and stacking manner of the grooves according to the design requirements of the display apparatus **100** to improve the adhesion between the sealant **109** and the substrate **104**.

(54) According to above embodiments of the present disclosure, a display apparatus is provided, wherein at least one insulating layer is provided on the substrate for forming a thin film transistor, and a plurality of grooves are formed in a portion of the insulating layer disposed in a frame region of the display apparatus. An alignment film and a sealant are then formed on the portion of the insulating layer disposed in the frame region to make the projection of sealant onto the substrate at least overlapping with a portion of the plurality of grooves. Thereby, the surface contacts between the sealant and the insulating layer can be increased, and the adhesion between the sealant and the substrate can be improved by the aid of the surface contacts to prevent the sealant from being peeled off from the substrate.

(55) While the invention has been described by way of example and in terms of the preferred embodiment(s), it is to be understood that the invention is not limited thereto. On the contrary, it is intended to cover various modifications and similar arrangements and procedures, and the scope of the appended claims therefore should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements and procedures.

Claims

1. A substrate assembly, comprising: a substrate; a first insulating layer, disposed on the substrate, wherein the first insulating layer comprises a first groove, a second groove adjacent to the first groove, and a protrusion disposed between the first groove and the second groove; and a second insulating layer, disposed on the first insulating layer; wherein in a top view, the first groove has a first edge and a second edge, the second edge is closer to the protrusion than the first edge along a direction, the second groove has a third edge and a fourth edge, and the third edge is closer to the protrusion than the fourth edge along the direction; wherein in the top view, the first groove has a width S defined by a distance between the first edge and the second edge along the direction, and the protrusion has a width P defined by a distance between the second edge and the third edge along the direction; wherein in a cross-sectional view, the protrusion has a sidewall and a bottom, the sidewall and the bottom of the protrusion form an angle θ, d is a height of the protrusion of the first insulating layer, and t is a height of the second insulating layer, wherein the width P of the protrusion satisfies a formula as follows:
P≤[S(d−t)−d.sup.2 Cot θ]/*t;* wherein S, P, t and d have the same unit.
2. The substrate assembly according to claim 1, wherein the angle is in a range from 15 degrees to 75 degrees.
3. The substrate assembly according to claim 1, wherein the height of the second insulating layer is in a range from 0.05 μm and 0.15 μm.
4. The substrate assembly according to claim 1, wherein the first insulating layer is formed of an organic material.
5. The substrate assembly according to claim 1, wherein in the cross-sectional view, at least a part

of the protrusion has a curved shape.
6. The substrate assembly according to claim 1, wherein in the cross-sectional view, at least a part of the sidewall of the protrusion has a curved shape.
7. The substrate assembly according to claim 1, further comprising a gate electrode disposed on the substrate, wherein the first insulating layer is disposed between the gate electrode and the second insulating layer.
8. A display apparatus comprising: the substrate assembly according to claim 1; another substrate; and a liquid crystal layer disposed between the substrate assembly and the another substrate.
