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(54) **LIQUID CRYSTAL DISPLAY DEVICE**

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G02F 1/1333 (2006.01)

(52) **U.S. Cl.**
USPC **349/138**; 349/141

(58) **Field of Classification Search**
USPC 349/138
See application file for complete search history.

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(57) **ABSTRACT**

Provided is a liquid crystal display device (100), including a pixel electrode (Px) and a common electrode (CT) which are stacked via an insulating layer, one of the pixel electrode (Px) and the common electrode (CT) including slits (SL) formed therein, for aligning liquid crystal molecules by an electric field generated by the pixel electrode (Px) and the common electrode (CT), in which the insulating layer is formed so as to increase in thickness from a vicinity of ends (13a, 13b) in a longitudinal direction of the slits (SL) toward the ends (13a, 13b). Thus, the transmittance of the liquid crystal display device is improved.

16 Claims, 9 Drawing Sheets

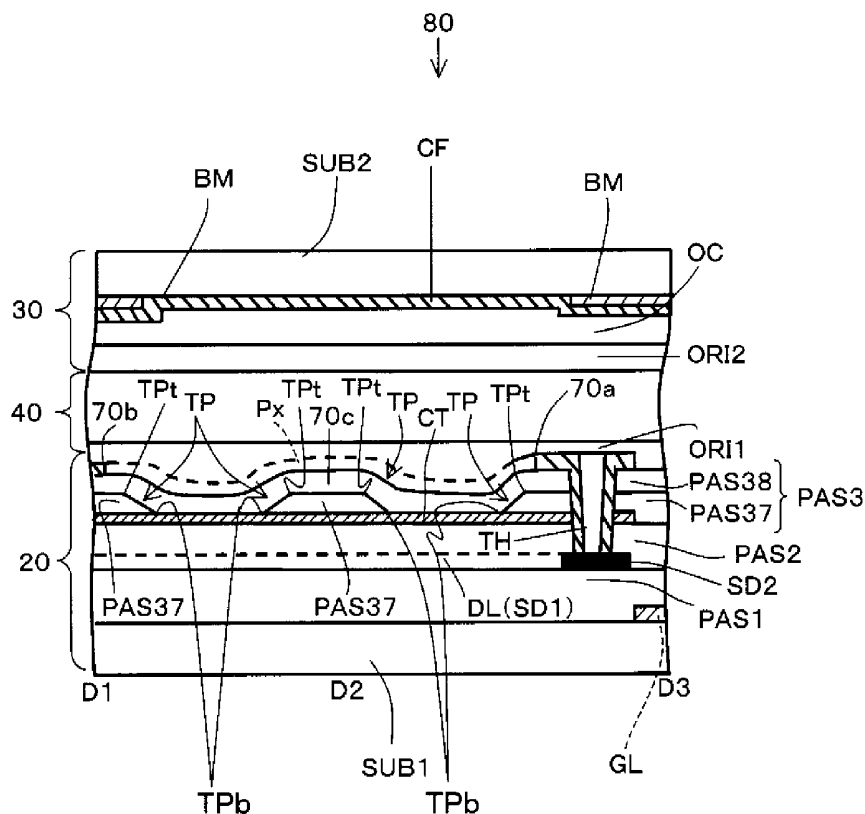


FIG. 1

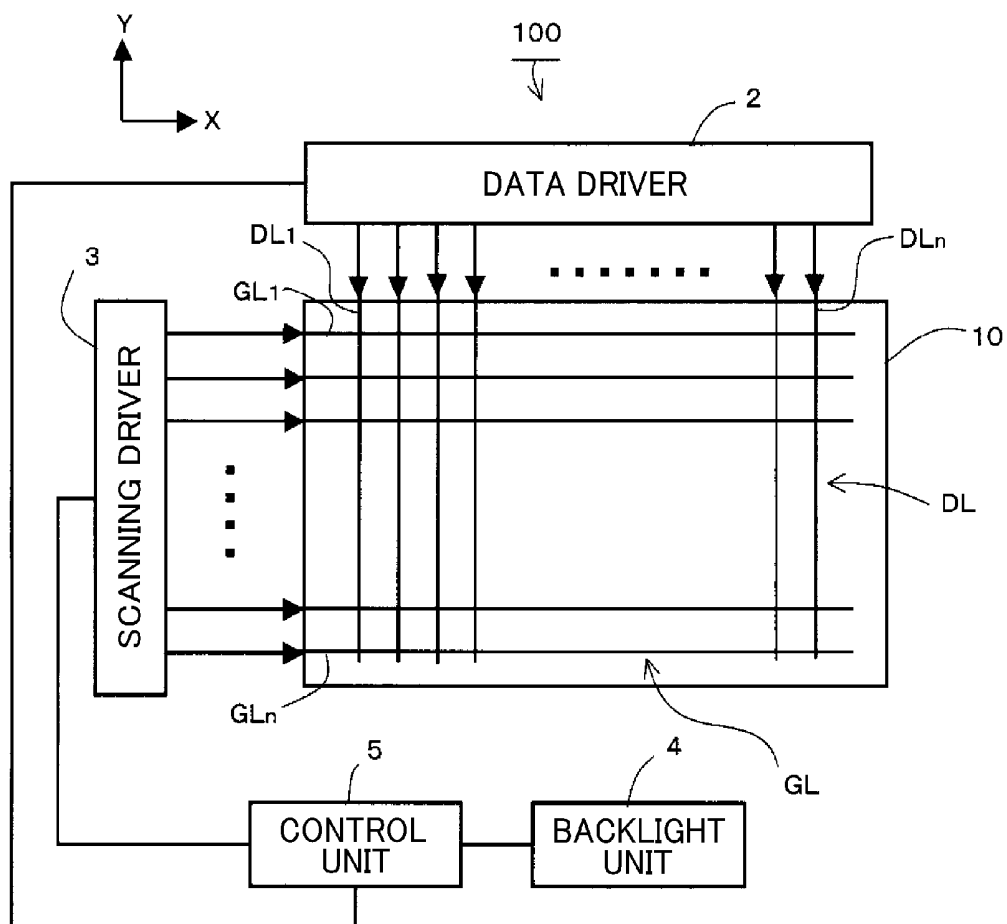


FIG.2

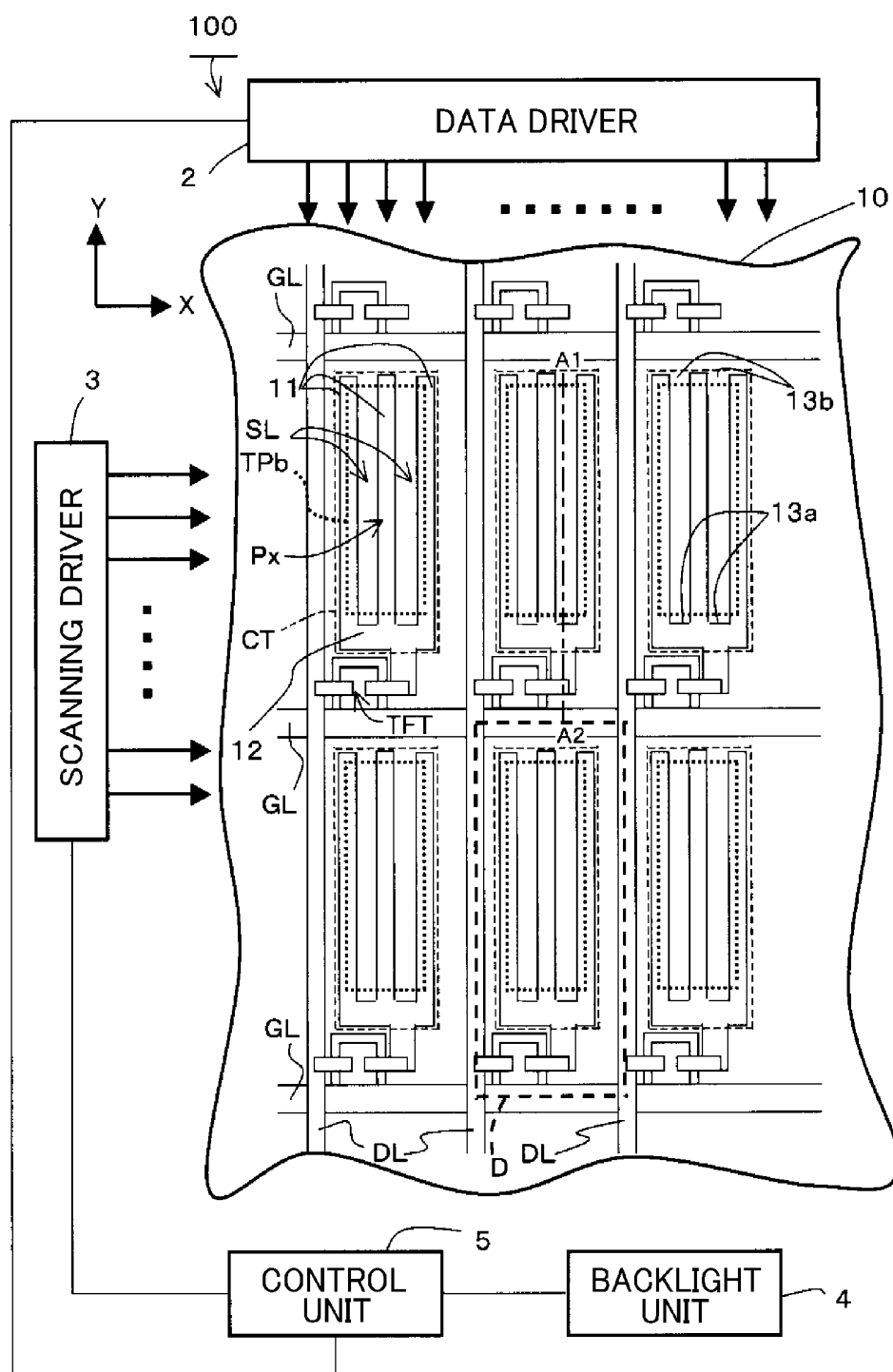


FIG. 3

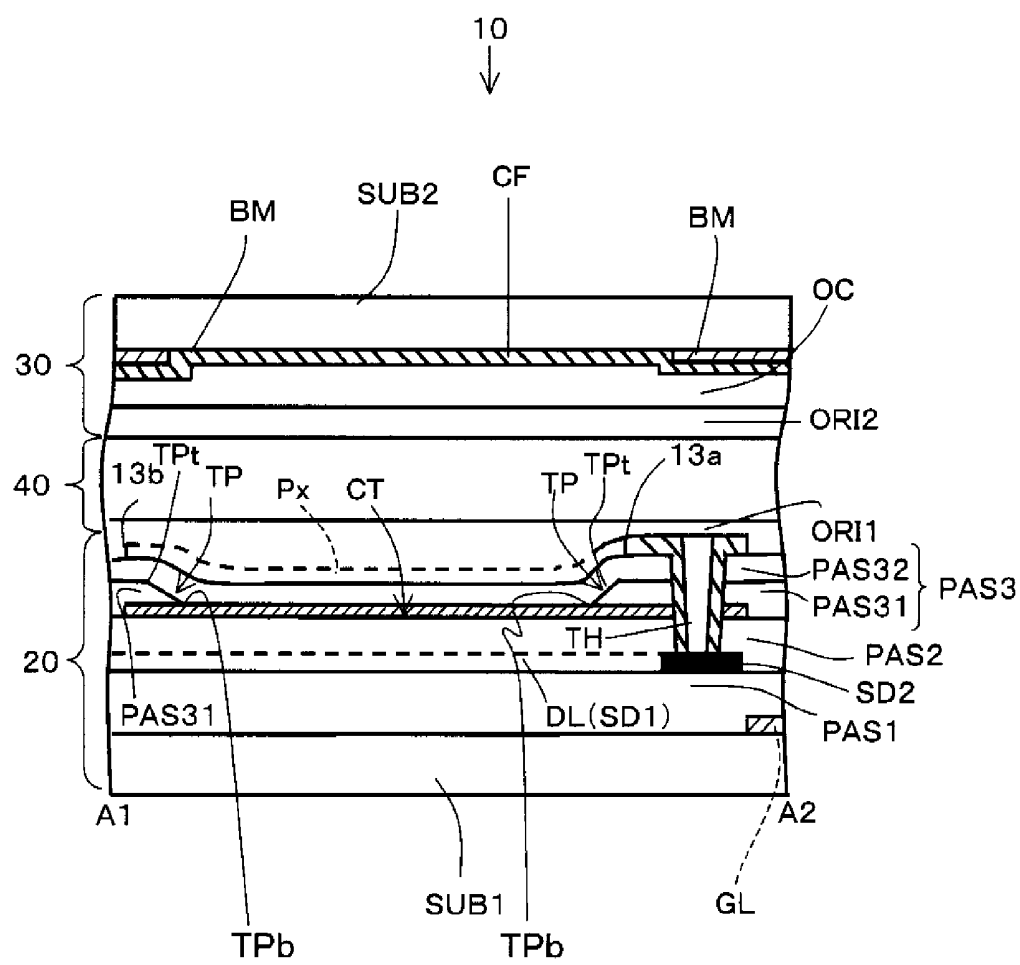


FIG. 4

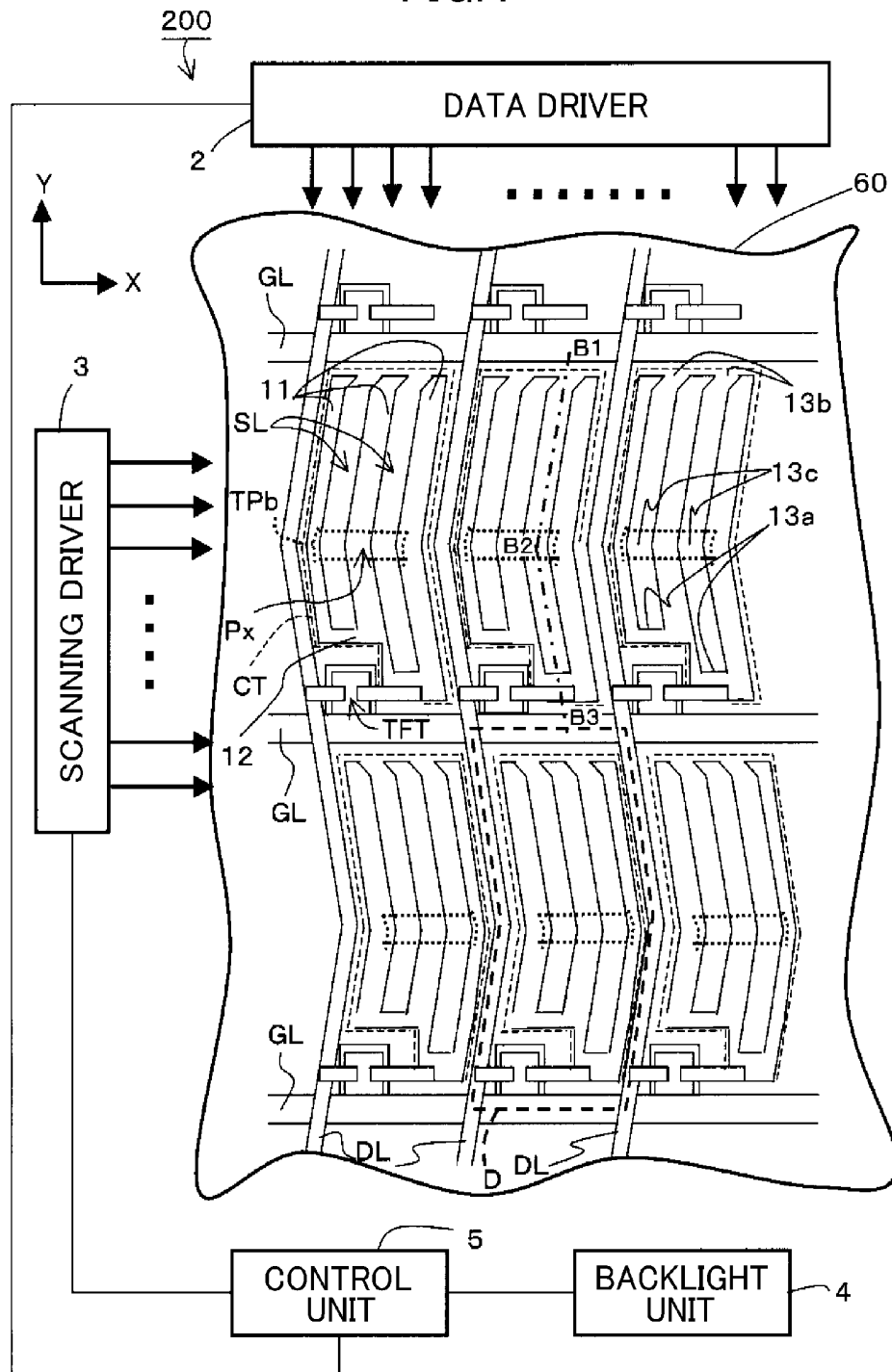


FIG.5

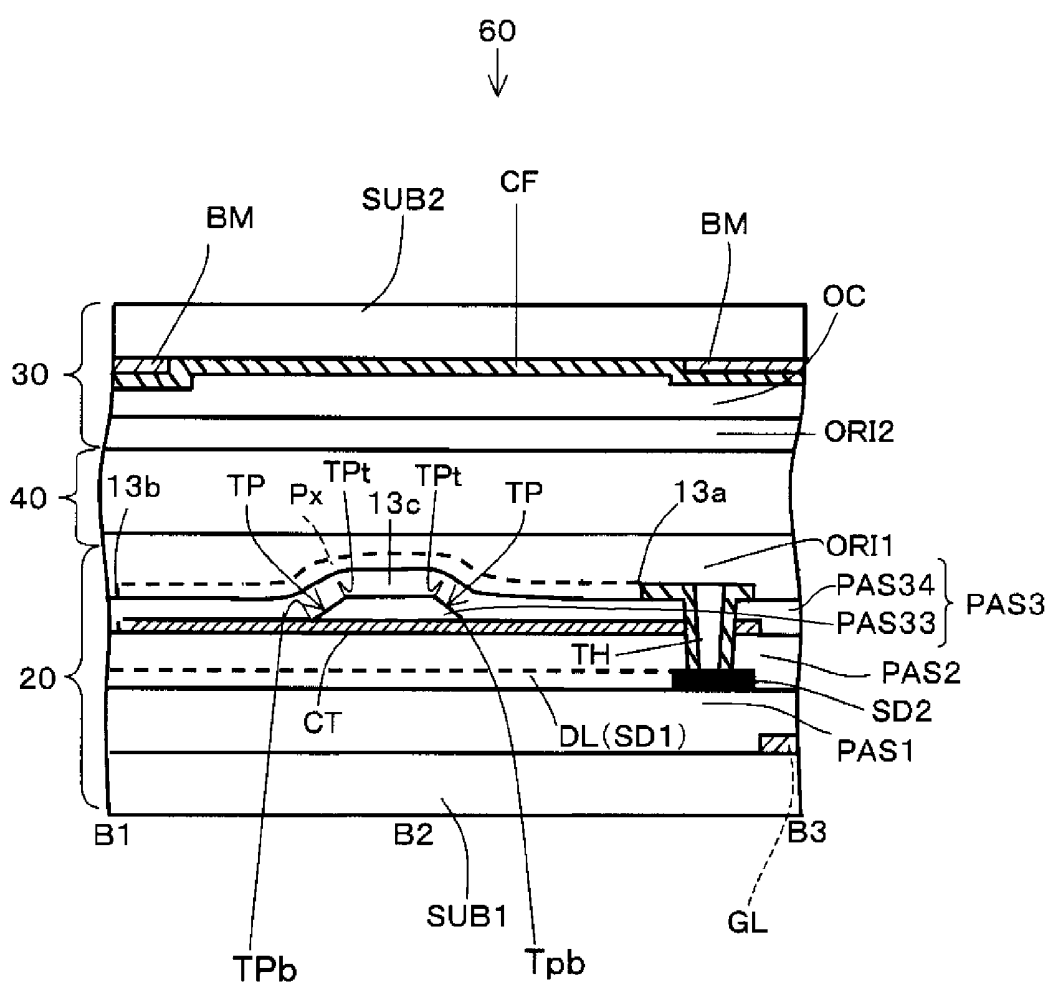


FIG.6

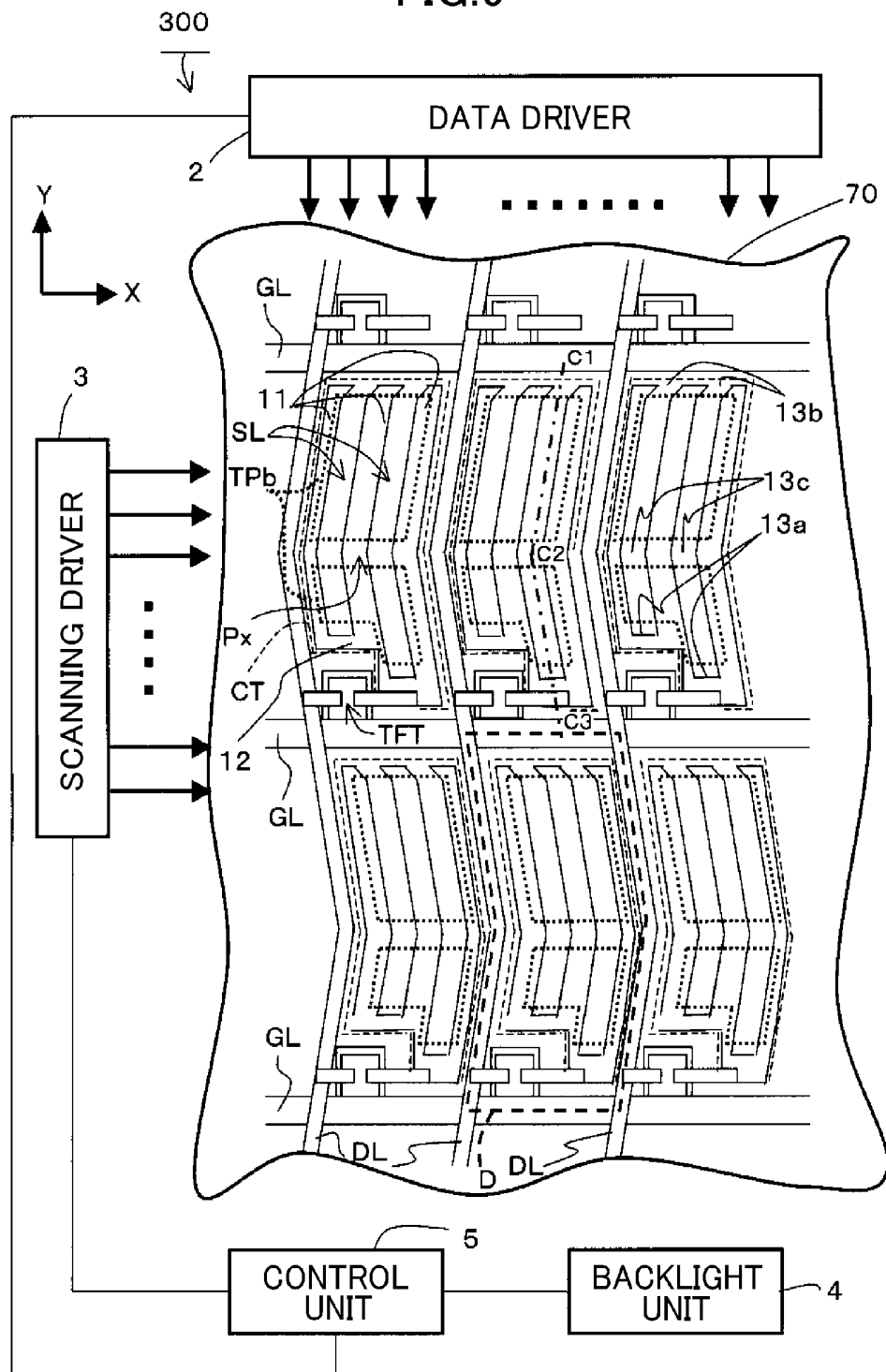


FIG. 7

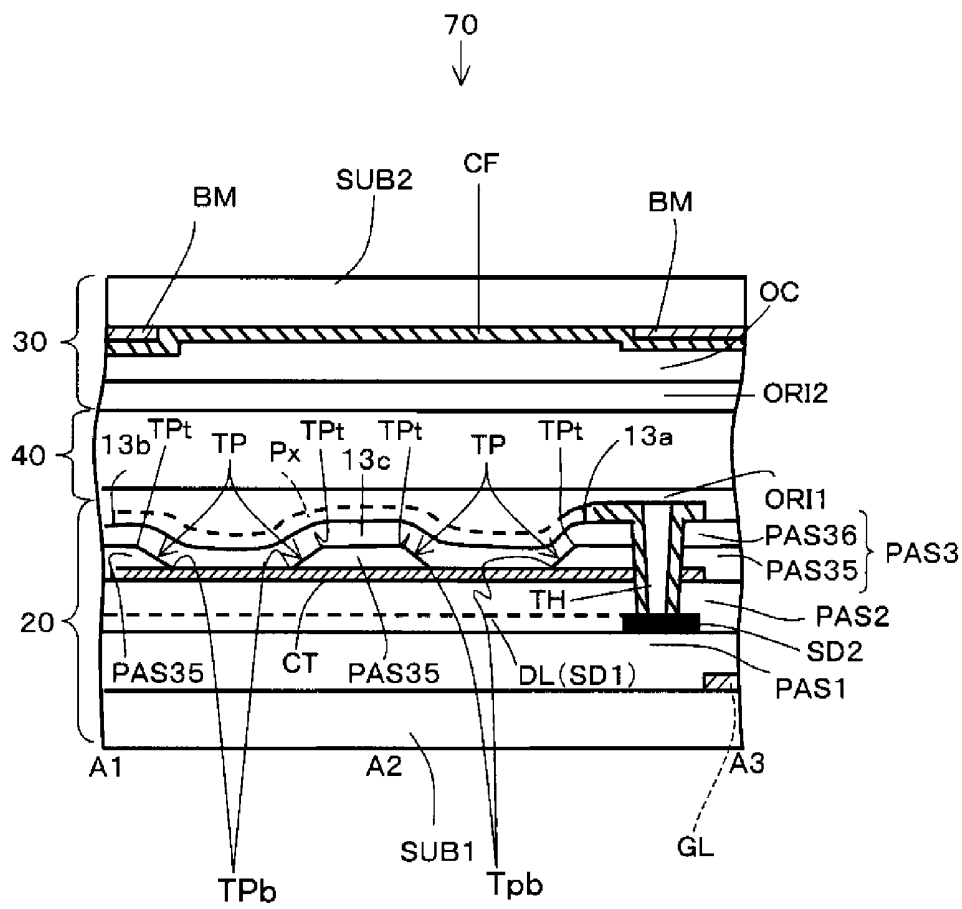


FIG. 8

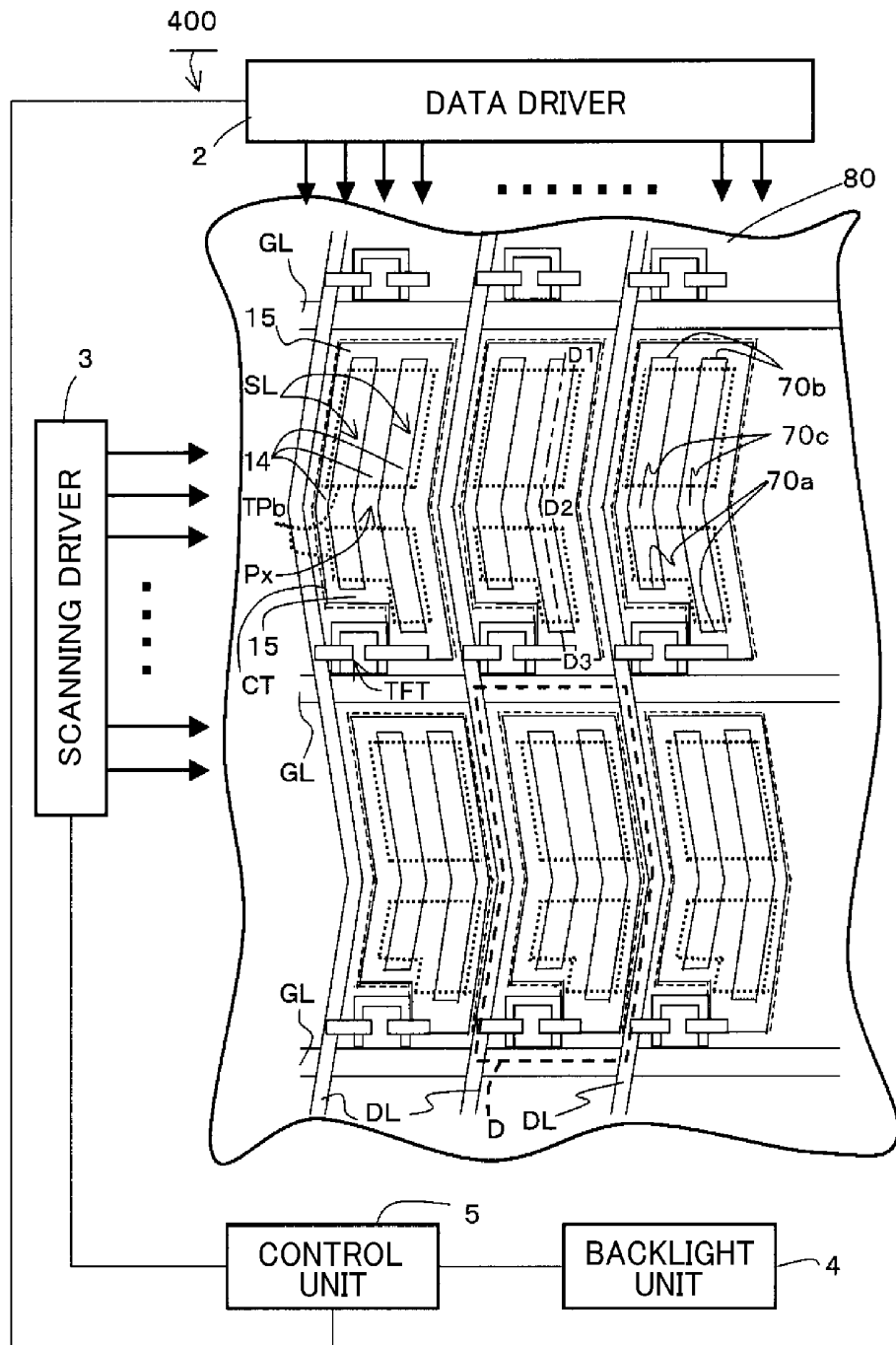
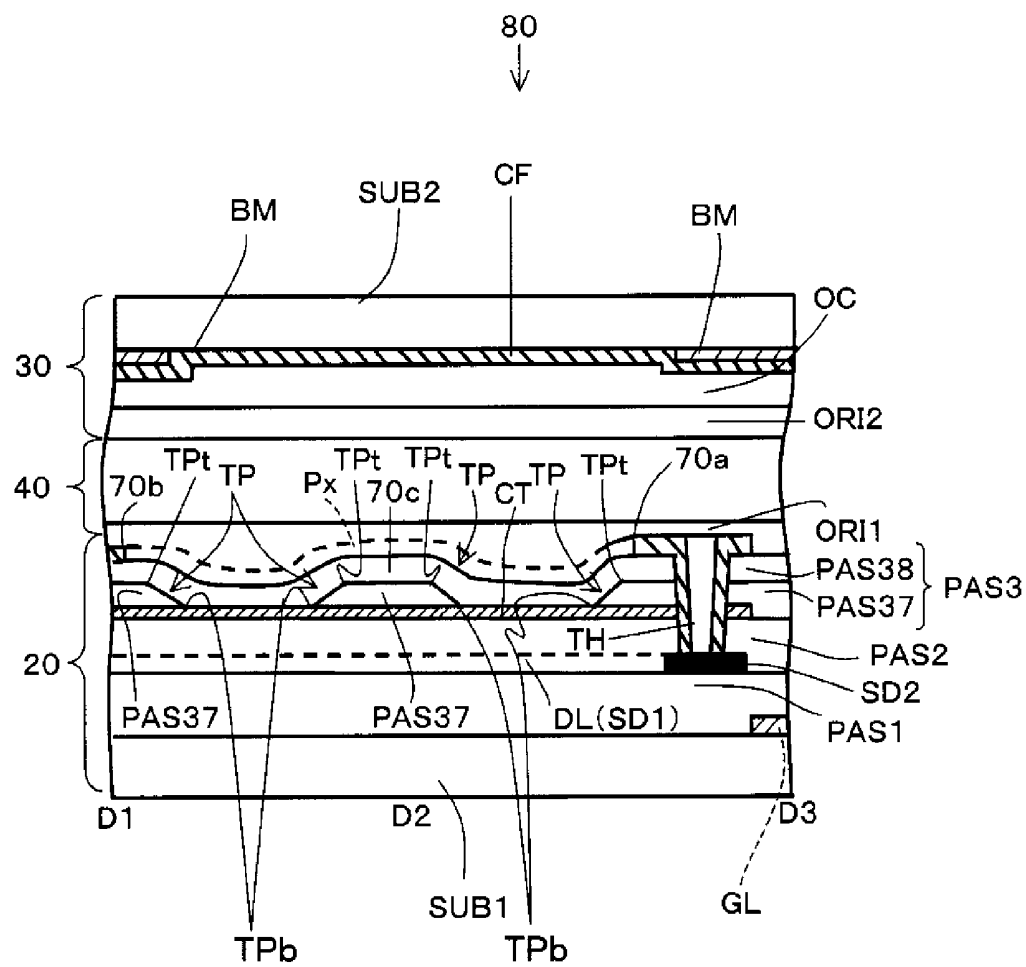


FIG. 9



LIQUID CRYSTAL DISPLAY DEVICE**CROSS-REFERENCE TO RELATED APPLICATION**

The present application claims priority from Japanese application JP 2010-236077 filed on Oct. 21, 2010, the content of which is hereby incorporated by reference into this application.

BACKGROUND OF THE INVENTION**1. Field of the Invention**

The present invention relates to a liquid crystal display device in which liquid crystal molecules are aligned by an electric field generated by two electrodes stacked via an insulating layer.

2. Description of the Related Art

Conventionally, liquid crystal display devices are classified into ones of a vertical electric field system and ones of a horizontal electric field system. A liquid crystal display device of the horizontal electric field system may obtain wider viewing angle characteristics compared with those of a liquid crystal display device of the vertical electric field system. Among liquid crystal display devices of the horizontal electric field system, ones in which a pixel electrode and a common electrode are stacked via an insulating layer, one of the electrodes having slits formed therein and the other of the electrodes being in the shape of an even plane without an opening, are used when high transmittance is required. This is because an arc-like electric flux is distributed to the vicinity of the center of the electrode having the slits formed therein so as to connect the pixel electrode and the common electrode which are in different layers.

By the way, examples of the electrode having slits formed therein include a comb electrode in which one ends of the slits are closed while the other ends are open, and an electrode in which both the ends of the slits are closed. Further, in a multi-domain liquid crystal display device, such slits in the electrode are inflected. When an electric field is generated by an electrode having slits formed therein and an electrode in the shape of an even plane without an opening, an electric field in the vicinity of ends in a longitudinal direction of the slits or in the vicinity of inflected portions of the slits is distributed in such a way that control of the alignment of the liquid crystal molecules is difficult. Therefore, a region in which the alignment of the liquid crystal molecules cannot be controlled (hereinafter, referred to as domain) is generated in the vicinity of the ends in the longitudinal direction of the slits or in the vicinity of the inflected portions of the slits. The domain is responsible for lowering the transmittance in the liquid crystal display device. Accordingly, as disclosed in, for example, Japanese Patent Application Laid-open No. 2008-276172, a liquid crystal display device which reduces such a domain has been proposed.

SUMMARY OF THE INVENTION

In the liquid crystal display device disclosed in Japanese Patent Application Laid-open No. 2008-276172, the number of ends of slits is reduced by providing the slits so as to extend continuously over a plurality of pixels. In other words, in the liquid crystal display device, the domain is reduced by reducing the number of ends of slits which are responsible for generation of the domain.

However, in the liquid crystal display device disclosed in Japanese Patent Application Laid-open No. 2008-276172,

not all the ends of slits are eliminated, and thus, the problem that a domain generated in the vicinity of ends of slits lowers the transmittance is not solved.

The present invention has been made in view of the above, and an object of the present invention is to provide a liquid crystal display device which improves the transmittance.

In order to solve the above-mentioned problem and to achieve the object, according to a first aspect of the present invention, there is provided a liquid crystal display device, including a pixel electrode; and a common electrode generating an electric field to align liquid crystal molecules in cooperation with the pixel electrode; and an insulating layer which is stacked between the pixel electrode and the common electrode; wherein one of the pixel electrode and the common electrode included slits formed therein, and the insulating layer is formed so as to increase in thickness from a vicinity of ends in a longitudinal direction of the slits toward the ends.

Further, in the liquid crystal display device according to the first aspect of the present invention, the insulating layer may be formed so as to gradually increase in thickness from the vicinity of the ends in the longitudinal direction of the slits toward the ends.

Further, in the liquid crystal display device according to the first aspect of the present invention, the insulating layer may be processed to be inclined in advance so as to increase in thickness from the vicinity of the ends in the longitudinal direction of the slits toward the ends.

Further, in the liquid crystal display device according to the first aspect of the present invention, the vicinity of the ends in the longitudinal direction of the slits may be a domain generating region.

Further, in order to solve the above-mentioned problem and to achieve the object, according to a second aspect of the present invention, there is provided a liquid crystal display device, including a pixel electrode; a common electrode generating an electric field to align liquid crystal molecules in cooperation with the pixel electrode; and an insulating layer which is stacked between the pixel electrode and the common electrode; wherein one of the pixel electrode and the common electrode includes slits formed therein, and the slits are inflected, and the insulating layer is formed so as to increase in thickness from a vicinity of inflected portions of the slits toward the inflected portions.

Further, in the liquid crystal display device according to the second aspect of the present invention, the insulating layer may be formed so as to gradually increase in thickness from the vicinity of the inflected portions of the slits toward the inflected portions.

Further, in the liquid crystal display device according to the second aspect of the present invention, the insulating layer may be processed to be inclined in advance so as to increase in thickness from the vicinity of the inflected portions of the slits toward the inflected portions.

Further, in the liquid crystal display device according to the second aspect of the present invention, the vicinity of the inflected portions may be a domain generating region.

Further, in order to solve the above-mentioned problem and to achieve the object, according to a third aspect of the present invention, there is provided a liquid crystal display device, including a pixel electrode; a common electrode generating an electric field to align liquid crystal molecules in cooperation with the pixel electrode; and an insulating layer which is stacked between the pixel electrode and the common electrode; wherein one of the pixel electrode and the common electrode includes slits formed therein the slits are inflected, and the insulating layer is formed so as to increase in thickness from a vicinity of ends in a longitudinal direction of the

slits toward the ends and is formed so as to increase in thickness from a vicinity of inflected portions of the slits toward the inflected portions.

Further, in the liquid crystal display device according to the third aspect of the present invention, the insulating layer may be formed so as to gradually increase in thickness from the vicinity of the ends in the longitudinal direction of the slits toward the ends and so as to gradually increase in thickness from the vicinity of the inflected portions of the slits toward the inflected portions.

Further, in the liquid crystal display device according to the third aspect of the present invention, the insulating layer may be processed to be inclined in advance so as to increase in thickness from the vicinity of the ends in the longitudinal direction of the slits toward the ends and so as to increase in thickness from the vicinity of the inflected portions of the slits toward the inflected portions.

Further, in the liquid crystal display device according to the third aspect of the present invention, the vicinity of the ends in the longitudinal direction of the slits and the vicinity of the inflected portions may be domain generating regions.

Further, in the liquid crystal display device according to the present invention, the one of the pixel electrode and the common electrode including the slits formed therein may be a comb electrode, and one of the ends in the longitudinal direction of the slits may be open while another end is closed.

Further, in the liquid crystal display device according to the present invention, the ends in the longitudinal direction of the slits may be closed.

In the liquid crystal display device according to the present invention in which the pixel electrode and the common electrode are stacked via the insulating layer, the slits are formed in one of the pixel electrode and the common electrode, and the liquid crystal molecules are aligned by an electric field generated by the pixel electrode and the common electrode, the insulating layer is formed so as to increase in thickness from the vicinity of the ends in the longitudinal direction of the slits toward the ends, to thereby lower the intensity of the electric field in the vicinity of the ends in the longitudinal direction of the slits. Because of the lowered intensity of the electric field, the liquid crystal molecules are normally aligned around the ends in the longitudinal direction of the slits and thus suppress enlargement of a domain which is generated by the electric field in the vicinity of the ends in the longitudinal direction of the slits. Therefore, the domain reduces, and, as a consequence, the transmittance may be improved.

Further, in the liquid crystal display device according to the present invention in which the pixel electrode and the common electrode are stacked via the insulating layer, the slits are formed in one of the pixel electrode and the common electrode, and the liquid crystal molecules are aligned by an electric field generated by the pixel electrode and the common electrode, the slits are formed so as to be inflected, and the insulating layer is formed so as to increase in thickness from the vicinity of the inflected portions of the slits toward the inflected portions, to thereby lower the intensity of the electric field in the vicinity of the inflected portions of the slits. Because of the lowered intensity of the electric field, the liquid crystal molecules are normally aligned around the inflected portions of the slits and thus suppress enlargement of a domain which is generated by the electric field in the vicinity of the inflected portions of the slits. Therefore, the domain reduces, and, as a consequence, the transmittance may be improved.

Further, in the liquid crystal display device according to the present invention in which the pixel electrode and the com-

mon electrode are stacked via the insulating layer, the slits are formed in one of the pixel electrode and the common electrode, and the liquid crystal molecules are aligned by an electric field generated by the pixel electrode and the common electrode, the slits are formed so as to be inflected, the insulating layer is formed so as to increase in thickness from the ends in the longitudinal direction of the slits toward the ends, and the insulating layer is formed so as to increase in thickness from the vicinity of the inflected portions of the slits toward the inflected portions, to thereby lower the intensity of the electric field in the vicinity of the ends in the longitudinal direction of the slits and in the vicinity of the inflected portions. Because of the lowered intensity of the electric field, the liquid crystal molecules are normally aligned around the ends in the longitudinal direction of the slits and around the inflected portions and thus suppress enlargement of a domain which is generated by the electric field in the vicinity of the ends in the longitudinal direction of the slits and in the vicinity of the inflected portions. Therefore, the domain reduces, and, as a consequence, the transmittance may be improved.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

FIG. 1 is a schematic view illustrating a structure of a liquid crystal display device according to a first embodiment of the present invention;

FIG. 2 is a detailed explanatory diagram of a structure of a liquid crystal display panel illustrated in FIG. 1;

FIG. 3 is a cross-sectional view of the liquid crystal display panel taken along the line A1-A2 of FIG. 2;

FIG. 4 is a detailed explanatory diagram of a structure of a liquid crystal display panel of a liquid crystal display device according to a second embodiment of the present invention;

FIG. 5 is a cross-sectional view of the liquid crystal display panel taken along the line B1-B2-B3 of FIG. 4;

FIG. 6 is a detailed explanatory diagram of a structure of a liquid crystal display panel of a liquid crystal display device according to a third embodiment of the present invention;

FIG. 7 is a cross-sectional view of the liquid crystal display panel taken along the line C1-C2-C3 of FIG. 6;

FIG. 8 is a detailed explanatory diagram of a structure of a liquid crystal display panel of a liquid crystal display device according to a fourth embodiment of the present invention; and

FIG. 9 is a cross-sectional view of the liquid crystal display panel taken along the line D1-D2-D3 of FIG. 8.

DETAILED DESCRIPTION OF THE INVENTION

Liquid crystal display devices according to preferred embodiments of the present invention are described in detail in the following with reference to the attached drawings.

[First Embodiment]

FIG. 1 is a schematic view illustrating a structure of a liquid crystal display device 100 according to a first embodiment of the present invention. FIG. 2 is a detailed explanatory diagram of a structure of a liquid crystal display panel 10 illustrated in FIG. 1. In FIG. 2, the part of a liquid crystal display panel 10 is enlarged to explain the structure of pixels. FIG. 3 is a cross-sectional view of the liquid crystal display panel 10 taken along the line A1-A2 of FIG. 2. The liquid crystal display device 100 is of the horizontal electric field system, and includes the liquid crystal display panel 10, a data driver 2, a scanning driver 3, a backlight unit 4, and a control unit 5.

As illustrated in FIG. 1, the liquid crystal display panel 10 includes a plurality of video signal lines DL (DL₁, . . . , DL_n),

where n is a natural number) which extend in a Y direction and a plurality of scanning signal lines GL ($GL_1, \dots, GL_m$, where m is a natural number) which extend in an X direction. Further, in the liquid crystal display panel **10**, the plurality of scanning signal lines GL are formed so as to be in parallel to one another, and each of the plurality of video signal lines DL is formed so as to cross the scanning signal lines GL. A pixel D is formed in a region surrounded by those video signal lines DL and scanning signal lines GL.

As illustrated in FIG. 3, a liquid crystal material **40** containing liquid crystal molecules is sealed between a TFT substrate **20** and a counter substrate **30** in the liquid crystal display panel **10**. The TFT substrate **20** is a substrate including an insulating substrate such as a glass substrate, and the scanning signal lines GL, the video signal lines DL, thin film transistors TFTs, a common electrode CT, and pixel electrodes Px provided thereon. More specifically, the TFT substrate **20** has the scanning signal lines GL provided on an insulating substrate SUB1 such as a glass substrate. The scanning signal lines GL are formed by, for example, etching a film of a conductor such as aluminum.

The video signal line DL (source electrode SD1) and a drain electrode SD2 of the thin film transistor TFT are provided above the scanning signal line GL via a first insulating layer PAS1.

The common electrode CT is provided above the video signal line DL and the like via a second insulating layer PAS2. The common electrode CT is formed by etching a film of a conductor having high light transmittance such as ITO, and is formed in the shape of an even plane without an opening in a region which overlaps the pixel electrode Px in plan view. The pixel electrode Px is provided above the common electrode CT via a third insulating layer PAS3.

The pixel electrode Px is formed by etching a film of a conductor having high light transmittance such as ITO. The pixel electrode Px is connected to the drain electrode SD2 via a through hole TH. The pixel electrode Px has a plurality of slits SL formed in the region overlapping the common electrode CT in plan view, the slits SL having the long sides in a direction in which the video signal lines DL extend. The pixel electrode Px is a comb electrode, and one ends of the slits SL are open while the other ends of the slits SL are closed.

As illustrated in FIG. 2, the pixel electrode Px has a plurality of strip-like portions **11** formed in stripes and a joining portion **12** for joining one ends of the plurality of strip-like portions **11** together. The joining portion **12** is connected to the drain electrode SD2. The slits SL of the pixel electrode Px are formed by the strip-like portions **11** and the joining portion **12**.

The slits SL each have a closed end **13a** and an open end **13b**. The closed end **13a** is an end closed by the joining portion **12** of the ends in the longitudinal direction of the slit SL. The distribution of an electric field in the vicinity of the closed ends **13a** is affected not only by the strip-like portions **11** but also by the joining portion **12**. Specifically, the vicinity of the closed ends **13a** is a domain generating region. The open end **13b** is an open end of the ends in the longitudinal direction of the slit SL. The distribution of an electric field in the vicinity of the open ends **13b** is affected by tip portions of the strip-like portions **11**. Specifically, the vicinity of the open ends **13b** is a domain generating region.

As illustrated in FIG. 3, in the counter substrate **30**, a light shielding film BM called a black matrix and a color filter CF are provided on a surface of an insulating substrate SUB2 such as a glass substrate. The light shielding film BM is formed by, for example, etching a conductive film or an insulating film having alight transmittance of almost zero to

form a lattice-like pattern for separating the respective pixels D from one another. The color filter CF is formed by, for example, etching or exposing to light and developing an insulating film and periodically arranging a filter for displaying red (R), a filter for displaying green (G), and a filter for displaying blue (B) in an aperture region of the light shielding film. Further, an alignment film ORI2 is provided above the light shielding film BM and the color filter CF via, for example, an overcoating layer OC.

The data driver **2** generates video signals (gradation voltages) to be input to the plurality of video signal lines DL, respectively.

The scanning driver **3** sequentially inputs scanning signals to the plurality of scanning signal lines GL. The data driver **2** and the scanning driver **3** are electrically connected to the liquid crystal display panel **10** via a flexible board or the like (not shown) connected to an outer peripheral portion of the liquid crystal display panel **10**.

The backlight unit **4** is materialized by a light-emitting diode or the like, and irradiates light from a back surface side of the liquid crystal display panel **10**.

The control unit **5** is materialized by a CPU or the like, and is electrically connected to respective portions of the liquid crystal display device **100** including the data driver **2**, the scanning driver **3**, and the backlight unit **4**, for controlling the overall operation of the liquid crystal display device **100**. The control unit **5** includes a memory or the like (not shown) for temporarily holding video data which is input from an external system.

Here, the third insulating layer PAS3 is specifically described. As illustrated in FIG. 3, the third insulating layer PAS3 has a first inclination layer PAS31 and a second inclination layer PAS32.

The first inclination layer PAS31 is an insulating layer formed on the common electrode CT. The first inclination layer PAS31 has an inclined portion TP. The inclined portion TP is a portion of the first inclination layer PAS31 which is processed so as to form an inclined surface. The first inclination layer PAS31 starts its inclination at a bottom end TPb of the inclined portion TP and ends its inclination at a top end TPt. The inclined portion TP is processed in advance before the second inclination layer PAS32 is stacked thereon.

The inclined portion TP is inclined at a predetermined inclination angle with respect to a surface of the common electrode CT. For example, the inclined portion TP is inclined at an inclination angle of 10 degrees with respect to the surface of the common electrode CT. Note that, the inclination angle of the inclined portion TP is not limited to 10 degrees. In other words, the inclination angle may be appropriately set depending on the domain generating region. The first inclination layer PAS31 is processed to be inclined so as to gradually increase in thickness from the vicinity of the closed ends **13a** toward the closed ends **13a** and so as to gradually increase in thickness from the vicinity of the open ends **13b** toward the open ends **13b**.

The second inclination layer PAS32 is an insulating layer formed on the first inclination layer PAS31 after the first inclination layer PAS31 is processed to be inclined as described above.

The third insulating layer PAS3 is formed by the first inclination layer PAS31 which is processed to be inclined and the second inclination layer PAS32 which is stacked on the first inclination layer PAS31, so as to gradually increase in thickness from the vicinity of the closed ends **13a** toward the closed ends **13a** and so as to gradually increase in thickness from the vicinity of the open ends **13b** toward the open ends **13b**. Therefore, in the vicinity of the closed ends **13a** and in

the vicinity of the open ends **13b**, that is, in the domain generating regions, the intensity of the electric field generated by the pixel electrode Px and the common electrode CT becomes lower. Further, the intensity of the electric field changes so as to be gradually lowered toward the closed ends **13a** and toward the open ends **13b**, and thus, control of the alignment of the liquid crystal molecules is not adversely affected.

Note that, it is desired that the third insulating layer PAS3 gradually increase in thickness, but it is enough that the control of the alignment of the liquid crystal molecules is not adversely affected. For example, it is enough that the third insulating layer PAS3 increases in thickness from the vicinity of the closed ends **13a** toward the closed ends **13a** and from the vicinity of the open ends **13b** toward the open ends **13b**, respectively.

In the first embodiment of the present invention, the third insulating layer PAS3 is formed so as to gradually increase in thickness from the vicinity of the closed ends **13a** toward the closed ends **13a** and is formed so as to gradually increase in thickness from the vicinity of the open ends **13b** toward the open ends **13b**, to thereby lower the intensity of the electric field in the vicinity of the closed ends **13a** and in the vicinity of the open ends **13b**. Because of the lowered intensity of the electric field, liquid crystal molecules are normally aligned in the vicinity of the closed ends **13a** and in the vicinity of the open ends **13b** and thus suppress enlargement of a domain which is generated by the electric field in the vicinity of the closed ends **13a** and in the vicinity of the open ends **13b**. Therefore, the domain reduces, and, as a consequence, the transmittance may be improved.

Further, in the first embodiment of the present invention, the liquid crystal molecules which are normally aligned in the vicinity of the closed ends **13a** and in the vicinity of the open ends **13b** due to the lowered intensity of the electric field in the vicinity of the closed ends **13a** and in the vicinity of the open ends **13b** suppress the enlargement of the domain which is generated by the electric field in the vicinity of the closed ends **13a** and in the vicinity of the open ends **13b**, and thus, even when the screen of the liquid crystal display panel **10** is pressed, the enlargement of the domain may be suppressed and time necessary for the screen to return to its original state may be shortened.

[Second Embodiment]

Next, a second embodiment of the present invention is described with reference to FIG. 4 and FIG. 5. FIG. 4 is a detailed explanatory diagram of a structure of a liquid crystal display panel **60** of a liquid crystal display device **200** according to the second embodiment of the present invention. FIG. 5 is a cross-sectional view of the liquid crystal display panel **60** taken along the line B1-B2-B3 of FIG. 4. In the first embodiment of the present invention, the slits SL are in the shape of straight lines, but, in the second embodiment, the slits SL each have a inflected portion **13c**. The third insulating layer PAS3 is formed so as to gradually increase in thickness from the vicinity of the inflected portions **13c** toward the inflected portions **13c**. Other structures in the second embodiment are the same as those in the first embodiment, and like reference symbols are used to designate like structural elements.

As illustrated in FIG. 4, a pixel electrode Px has a plurality of strip-like portions **11** formed in stripes and a joining portion **12** for joining one ends of the plurality of strip-like portions **11** together. The strip-like portions **11** are inflected so as to be V-shaped. In the pixel electrode Px, the slits SL which are inflected to be V-shaped are formed by the strip-like portions **11** and the joining portion **12**.

The inflected portions **13c** correspond to the inflected shape of the pixel electrode Px. Such V-shaped slits SL are widely employed in multi-domain liquid crystal display devices. The distribution of an electric field in the vicinity of the inflected portions **13c** is affected by the inflected shape. Specifically, the vicinity of the inflected portions **13c** is a domain generating region. As illustrated in FIG. 5, an alignment film ORI1 is provided on the pixel electrode Px. Note that, the shape of the slits SL is not limited to being inflected so as to be V-shaped. It is enough that the slits SL have inflected portions which accommodate a multi-domain liquid crystal display device.

Here, the third insulating layer PAS3 is specifically described. As illustrated in FIG. 5, the third insulating layer PAS3 has a first inclination layer PAS33 and a second inclination layer PAS34.

The first inclination layer PAS33 is an insulating layer formed on the common electrode CT. The first inclination layer PAS33 is processed to be inclined so as to gradually increase in thickness from the vicinity of the inflected portions **13c** of the slits SL toward the inflected portions **13c**.

The second inclination layer PAS34 is an insulating layer formed on the first inclination layer PAS33 after the first inclination layer PAS33 is processed to be inclined as described above.

The third insulating layer PAS3 is formed by the first inclination layer PAS33 which is processed to be inclined and the second inclination layer PAS34 which is stacked on the first inclination layer PAS33, so as to gradually increase in thickness from the vicinity of the inflected portions **13c** of the slits SL toward the inflected portions **13c**. Therefore, in the vicinity of the inflected portions **13c**, that is, in the domain generating region, the intensity of the electric field generated by the pixel electrode Px and the common electrode CT becomes lower. Further, the intensity of the electric field changes so as to be gradually lowered toward the inflected portions **13c**, and thus, control of the alignment of the liquid crystal molecules is not adversely affected.

In the second embodiment of the present invention, the third insulating layer PAS3 is formed so as to gradually increase in thickness from the vicinity of the inflected portions **13c** toward the inflected portions **13c**, to thereby lower the intensity of the electric field in the vicinity of the inflected portions **13c**. Because of the lowered intensity of the electric field, liquid crystal molecules are normally aligned in the vicinity of the inflected portions **13c** and thus suppress enlargement of a domain which is generated by the electric field in the vicinity of the inflected portions **13c**. Therefore, the domain reduces, and, as a consequence, the transmittance may be improved.

Further, in the second embodiment of the present invention, the pixel electrode Px is inflected, and thus, restrictions on the viewing angle may be eased.

[Third Embodiment]

Next, a third embodiment of the present invention is described with reference to FIG. 6 and FIG. 7. FIG. 6 is a detailed explanatory diagram of a structure of a liquid crystal display panel **70** of a liquid crystal display device **300** according to the third embodiment of the present invention. FIG. 7 is a cross-sectional view of the liquid crystal display panel **70** taken along the line C1-C2-C3 of FIG. 6. In the second embodiment of the present invention, the third insulating layer PAS3 is formed so as to gradually increase in thickness from the vicinity of the inflected portions **13c** toward the inflected portions **13c**. In the third embodiment, further, the third insulating layer PAS3 is formed so as to gradually increase in thickness from the vicinity of the closed ends **13a**

toward the closed ends **13a** and is formed so as to gradually increase in thickness from the vicinity of the open ends **13b** toward the open ends **13b**. Other structures in the third embodiment are the same as those in the second embodiment, and like reference symbols are used to designate like structural elements.

Here, the third insulating layer **PAS3** is specifically described. As illustrated in FIG. 7, the third insulating layer **PAS3** has a first inclination layer **PAS35** and a second inclination layer **PAS36**.

The first inclination layer **PAS35** is processed to be inclined so as to gradually increase in thickness from the vicinity of the closed ends **13a** toward the closed ends **13a** and so as to gradually increase in thickness from the vicinity of the open ends **13b** toward the open ends **13b**. Further, the first inclination layer **PAS35** is processed to be inclined so as to gradually increase in thickness from the vicinity of the inflected portions **13c** toward the inflected portions **13c**.

The second inclination layer **PAS36** is an insulating layer formed on the first inclination layer **PAS35** after the first inclination layer **PAS35** is processed to be inclined as described above.

The third insulating layer **PAS3** is formed by the first inclination layer **PAS35** which is processed to be inclined and the second inclination layer **PAS36** which is stacked on the first inclination layer **PAS35**, so as to gradually increase in thickness from the vicinity of the closed ends **13a** toward the closed ends **13a** and so as to gradually increase in thickness from the vicinity of the open ends **13b** toward the open ends **13b**. Further, the third insulating layer **PAS3** is formed so as to gradually increase in thickness from the vicinity of the inflected portions **13c** toward the inflected portions **13c**. Therefore, in the vicinity of the closed ends **13a**, in the vicinity of the open ends **13b**, and in the vicinity of the inflected portions **13c**, that is, in the domain generating regions, the intensity of the electric field generated by the pixel electrode **Px** and the common electrode **CT** becomes lower. Further, the intensity of the electric field changes so as to be gradually lowered toward the closed ends **13a**, toward the open ends **13b**, and toward the inflected portions **13c**, and thus, control of the alignment of the liquid crystal molecules is not adversely affected.

In the third embodiment of the present invention, the third insulating layer **PAS3** is formed so as to gradually increase in thickness from the vicinity of the inflected portions **13c** toward the inflected portions **13c**, to thereby obtain the same effect as that in the second embodiment, and is formed so as to gradually increase in thickness from the vicinity of the closed ends **13a** toward the closed ends **13a** and so as to gradually increase in thickness from the vicinity of the open ends **13b** toward the open ends **13b**, to thereby lower the intensity of the electric field in the vicinity of the closed ends **13a** and in the vicinity of the open ends **13b**. Because of the lowered intensity of the electric field, liquid crystal molecules are normally aligned in the vicinity of the closed ends **13a** and in the vicinity of the open ends **13b** and thus suppress enlargement of a domain which is generated by the electric field in the vicinity of the closed ends **13a** and in the vicinity of the open ends **13b**. Therefore, the domain reduces, and, as a consequence, the transmittance may be improved. [Fourth Embodiment]

Next, a fourth embodiment of the present invention is described with reference to FIG. 8 and FIG. 9. FIG. 8 is a detailed explanatory diagram of a structure of a liquid crystal display panel **80** of a liquid crystal display device **400** according to the fourth embodiment of the present invention. FIG. 9 is a cross-sectional view of the liquid crystal display panel **80**

taken along the line D1-D2-D3 of FIG. 8. In the third embodiment, the pixel electrode **Px** of the liquid crystal display panel **70** is a comb electrode in which one ends of both ends in the longitudinal direction of the slits **SL** are open, but, in the fourth embodiment, the pixel electrode **Px** of the liquid crystal display panel **80** is an electrode in which both ends in the longitudinal direction of the slits **SL** are closed.

As illustrated in FIG. 8, the pixel electrode **Px** has a plurality of strip-like portions **14** formed in stripes and joining portions **15** each for joining ends of the plurality of strip-like portions **14** together on one side. The slits **SL** of the pixel electrode **Px** are formed by the strip-like portions **14** and the joining portions **15**.

The slits **SL** each have closed ends **70a** and **70b** and a inflected portion **70c**. The closed ends **70a** and **70b** are ends closed by the joining portions **15**. The distribution of an electric field in the vicinity of the closed ends **70a** and **70b** is affected not only by the strip-like portions **14** but also by the joining portions **15**. Specifically, the vicinities of the closed ends **70a** and **70b** are domain generating regions. The inflected portions **70c** correspond to the inflected shape of the pixel electrode **Px**. The distribution of an electric field in the vicinity of the inflected portions **70c** is affected by the inflected shape. Specifically, the vicinity of the inflected portions **70c** is a domain generating region. Further, as illustrated in FIG. 9, the third insulating layer **PAS3** has a first inclination layer **PAS37** and a second inclination layer **PAS38**. Other structures in the fourth embodiment are the same as those in the third embodiment, and like reference symbols are used to designate like structural elements.

As illustrated in FIG. 9, the first inclination layer **PAS37** is processed to be inclined so as to gradually increase in thickness from the vicinity of the closed ends **70a** toward the closed ends **70a** and so as to gradually increase in thickness from the vicinity of the closed ends **70b** toward the closed ends **70b**. Further, the third insulating layer **PAS3** is processed to be inclined so as to gradually increase in thickness from the vicinity of the inflected portions **70c** toward the inflected portions **70c**. The second inclination layer **PAS38** is an insulating layer formed on the first inclination layer **PAS37** after the first inclination layer **PAS37** is processed to be inclined as described above.

The third insulating layer **PAS3** is formed by the first inclination layer **PAS37** which is processed to be inclined and the second inclination layer **PAS38** which is stacked on the first inclination layer **PAS37**, so as to gradually increase in thickness from the vicinity of the closed ends **70a** toward the closed ends **70a** and so as to gradually increase in thickness from the vicinity of the closed ends **70b** to the closed ends **70b**. Further, the third insulating layer **PAS3** is processed to be inclined so as to gradually increase in thickness from the vicinity of the inflected portions **70c** toward the inflected portions **70c**.

In the fourth embodiment of the present invention, the insulating layer **PAS3** is formed so as to gradually increase in thickness from the vicinity of the closed ends **70a** toward the closed ends **70a**, so as to gradually increase in thickness from the vicinity of the closed ends **70b** toward the closed ends **70b**, and further so as to gradually increase in thickness from the vicinity of the inflected portions **70c** toward the inflected portions **70c**, to thereby lower the intensity of the electric field in the vicinities of the closed ends **70a** and **70b** and in the vicinity of the inflected portions **70c**. Because of the lowered intensity of the electric field, liquid crystal molecules are normally aligned in the vicinities of the closed ends **70a** and **70b** and in the vicinity of the inflected portions **70c** and thus suppress enlargement of a domain which is generated by the

electric field in the vicinities of the closed ends **70a** and **70b** and in the vicinity of the inflected portions **70c**. Therefore, even when the pixel electrode **Px** is a pixel electrode in which both ends of the slits **SL** are closed, the transmittance may be improved.

Note that, in the first to fourth embodiments of the present invention, the longitudinal direction of the slits **SL** is the direction in which the video signal lines **DL** extend, but the present invention is not limited thereto. For example, the longitudinal direction of the slits **SL** may be a direction in which the scanning signal lines **GL** extend.

Further, in the first to fourth embodiments of the present invention, the pixel electrode **Px** is provided above the common electrode **CT**, but the present invention is not limited thereto. For example, the arrangement may be upside down in which the pixel electrode **Px** is provided below the common electrode **CT**.

Further, in the first to fourth embodiments of the present invention, the pixel electrode **Px** has the slits **SL** formed therein and the common electrode **CT** is in the shape of an even plane without an opening, but the present invention is not limited thereto. For example, the pixel electrode **Px** may be in the shape of an even plane without an opening and the common electrode **CT** may have the slits **SL** formed therein.

Further, in the first to fourth embodiments of the present invention, the third insulating layer **PAS3** is gradually increased in thickness by processing the first inclination layer **PAS31**, **PAS33**, **PAS35**, or **PAS37** to be inclined in advance, but the present invention is not limited thereto. It is enough that the third insulating layer **PAS3** gradually increases in thickness from the vicinities of ends of the slits **SL** toward the ends of the slits **SL** or from the vicinity of the inflected portions of the slits **SL** toward the inflected portions. For example, the third insulating layer **PAS3** may have a single-layer structure and the single-layer-structured third insulating layer **PAS3** may be processed to be inclined in advance.

Further, in the first, second, and fourth embodiments of the present invention, the third insulating layer **PAS3** is gradually increased in thickness toward both the ends of the slits **SL**, but the present invention is not limited thereto. For example, the third insulating layer **PAS3** may gradually increase in thickness only toward one ends of the slits **SL**.

Further, in the fourth embodiment of the present invention, the slits **SL** are inflected, but the present invention is not limited thereto, and the slits **SL** may be in the shape of straight lines.

Note that, the present invention is not limited to the first to fourth embodiments of the present invention.

While there have been described what are at present considered to be certain embodiments of the invention, it will be understood that various modifications may be made thereto, and it is intended that the appended claims cover all such modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A liquid crystal display device comprising:

a pixel electrode;

a common electrode generating an electric field to align liquid crystal molecules in cooperation with the pixel electrode; and

an insulating layer which is stacked between the pixel electrode and the common electrode;

wherein one of the pixel electrode and the common electrode includes slits formed therein, the slits of the one of the pixel electrode and the common electrode extending in parallel to each other in an extending direction; and

wherein the insulating layer in a region of the slits is formed so as to increase in thickness in the extending direction of the slits from a vicinity of ends of the slits toward the ends of the slits.

2. The liquid crystal display device according to claim 1, wherein the insulating layer is formed so as to gradually increase in thickness in the extending direction of the slits from the vicinity of the ends of the slits toward the ends of the slits.

3. The liquid crystal display device according to claim 1, wherein the insulating layer is processed to be inclined in advance so as to increase in thickness in the extending direction of the slits from the vicinity of the ends of the slits toward the ends of the slits.

4. The liquid crystal display device according to claim 1, wherein the vicinity of the ends of the slits in the extending direction of the slits is a domain generating region.

5. A liquid crystal display device comprising:

a pixel electrode;

a common electrode generating an electric field to align liquid crystal molecules in cooperation with the pixel electrode; and

an insulating layer which is stacked between the pixel electrode and the common electrode; wherein:

one of the pixel electrode and the common electrode includes slits formed therein, the slits of the one of the pixel electrode and the common electrode extending in parallel to each other in an extending direction;

the slits have inflected portions along the extending direction of the slits; and

the insulating layer in a region of the slits is formed so as to increase in thickness in the extending direction of the slits from a vicinity of the inflected portions of the slits toward the inflected portions of the slits.

6. The liquid crystal display device according to claim 5, wherein the insulating layer is formed so as to gradually increase in thickness in the extending direction of the slits from the vicinity of the inflected portions of the slits toward the inflected portions of the slits.

7. The liquid crystal display device according to claim 5, wherein the insulating layer is processed to be inclined in advance so as to increase in thickness in the extending direction of the slits from the vicinity of the inflected portions of the slits toward the inflected portions of the slits.

8. The liquid crystal display device according to claim 5, wherein the vicinity of the inflected portions of the slits is a domain generating region.

9. A liquid crystal display device comprising

a pixel electrode;

a common electrode generating an electric field to align liquid crystal molecules in cooperation with the pixel electrode; and

an insulating layer which is stacked between the pixel electrode and the common electrode; wherein:

one of the pixel electrode and the common electrode includes slits formed therein, the slits of the one of the pixel electrode and the common electrode extending in parallel to each other in an extending direction;

the slits have inflected portions along the extending direction of the slits; and

the insulating layer in a region of the slits is formed so as to increase in thickness in the extending direction of the slits from a vicinity of ends of the slits toward the ends of the slits and is formed so as to increase in thickness in the extending direction of the slits from a vicinity of the inflected portions of the slits toward the inflected portions of the slits.

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10. The liquid crystal display device according to claim 9, wherein the insulating layer is formed so as to gradually increase in thickness in the extending direction of the slits from the vicinity of the ends of the slits toward the ends of the slits and so as to gradually increase in thickness from the vicinity of the inflected portions of the slits toward the inflected portions of the slits.

11. The liquid crystal display device according to claim 9, wherein the insulating layer is processed to be inclined in advance so as to increase in thickness in the extending direction of the slits from the vicinity of the ends of the slits toward the ends of the slits and so as to increase in thickness from the vicinity of the inflected portions of the slits toward the inflected portions of the slits.

12. The liquid crystal display device according to claim 9, wherein the vicinity of the ends of the slits in the extending direction of the slits and the vicinity of the inflected portions of the slits are domain generating regions.

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13. The liquid crystal display device according to claim 1, wherein the one of the pixel electrode and the common electrode including the slits formed therein comprises a comb electrode, and

wherein one of the ends of the slits in the extending direction of the slits is open while another end of the slits is closed.

14. The liquid crystal display device according to claim 1, wherein the ends of the slits in the extending direction of the slits are closed.

15. The liquid crystal display device according to claim 5, wherein the slits having the inflected portions are bent at the inflected portions of the slits so that the extending direction of the slits changes from the bent inflection portion thereof.

16. The liquid crystal display device according to claim 9, wherein the slits having the inflected portions are bent at the inflection portions of the slits so that the extending direction of the slits changes from the bent inflection portion thereof.

* * * * *

专利名称(译)	液晶显示装置		
公开(公告)号	US8670095	公开(公告)日	2014-03-11
申请号	US13/272304	申请日	2011-10-13
[标]申请(专利权)人(译)	株式会社日立显示器		
申请(专利权)人(译)	松下液晶显示CO., LTD. 日立显示器有限公司.		
当前申请(专利权)人(译)	松下液晶显示CO., LTD. 日本展示INC.		
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发明人	OUGIICHI, KIMITOSHI IMAYAMA, HIROTAKE		
IPC分类号	G02F1/1333		
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摘要(译)

提供一种液晶显示装置 (100) , 包括通过绝缘层堆叠的像素电极 (Px) 和公共电极 (CT) , 像素电极 (Px) 和包括狭缝的公共电极 (CT) 中的一个 (SL) 形成在其中, 用于通过由像素电极 (Px) 和公共电极 (CT) 产生的电场对准液晶分子, 其中形成绝缘层以便从端部附近增加厚度 (如图13a , 13b) 所示, 在狭缝 (SL) 的纵向方向上朝向端部 (13a , 13b) 。因此, 改善了液晶显示装置的透射率。

