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(54) **LIQUID CRYSTAL DISPLAY DEVICE**

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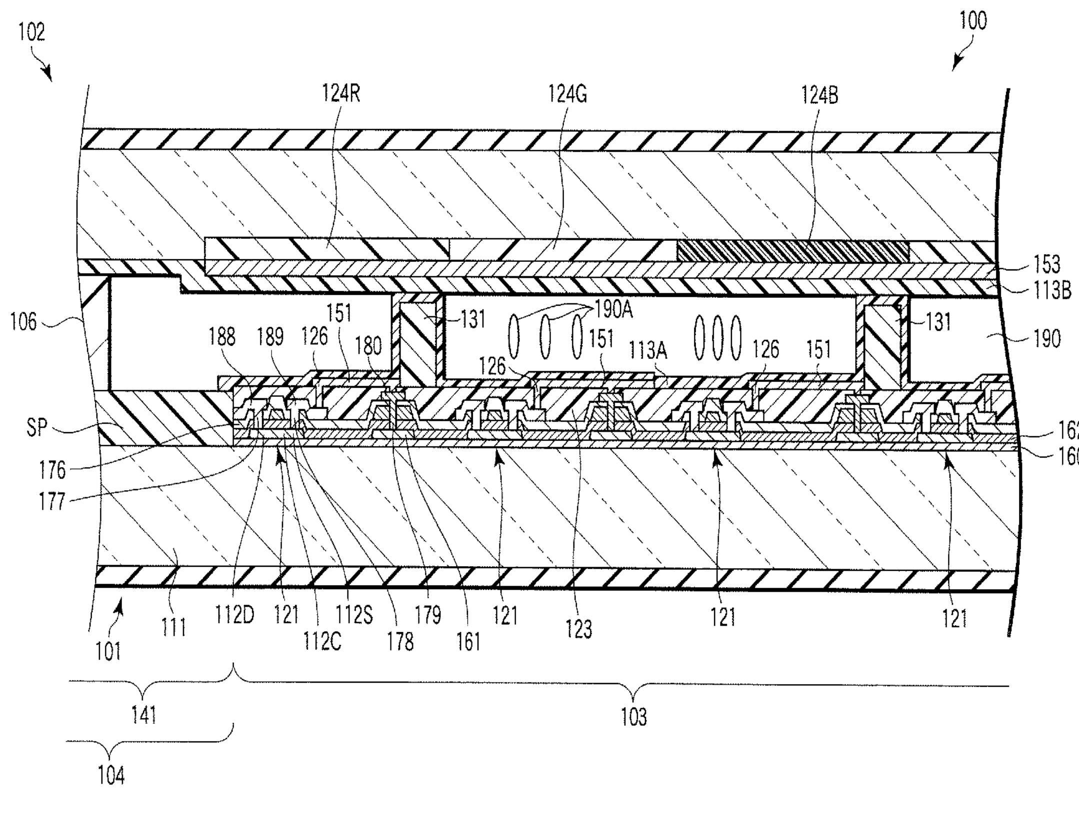
(57) **ABSTRACT**

A liquid crystal display device includes an array substrate and a counter-substrate, a liquid crystal layer which is held between the array substrate and counter-substrate and includes a transmissive display part and a reflective display part which neighbor each other via a boundary, an alignment state of liquid crystal molecules in the liquid crystal layer being controlled by an application voltage from the array substrate and counter-substrate in the transmissive display part and the reflective display part, and control means for making an alignment direction of the liquid crystal molecules, which are present near the boundary in the reflective display part, substantially match an alignment direction of the liquid crystal molecules which are present near the boundary in the transmissive display part.



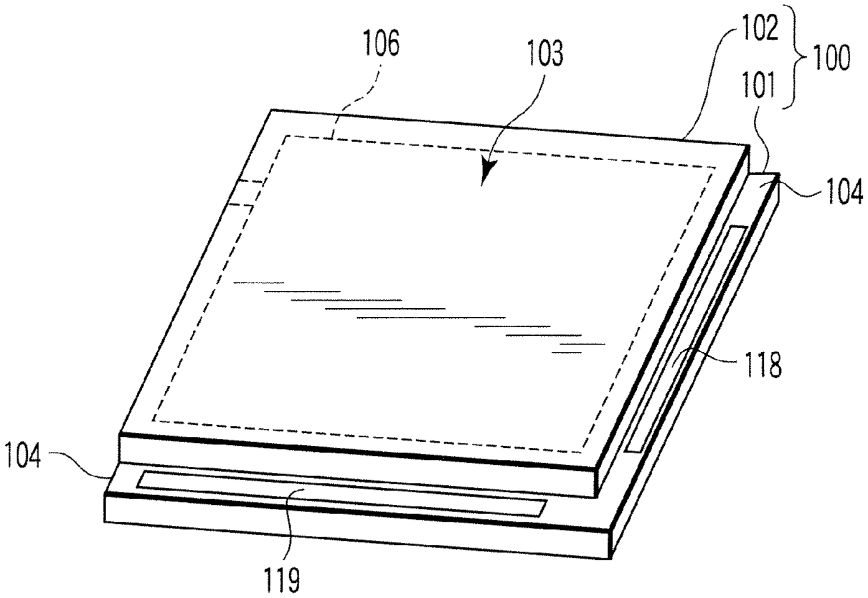

106
103
102
100
101
104
118
104
119

FIG. 1

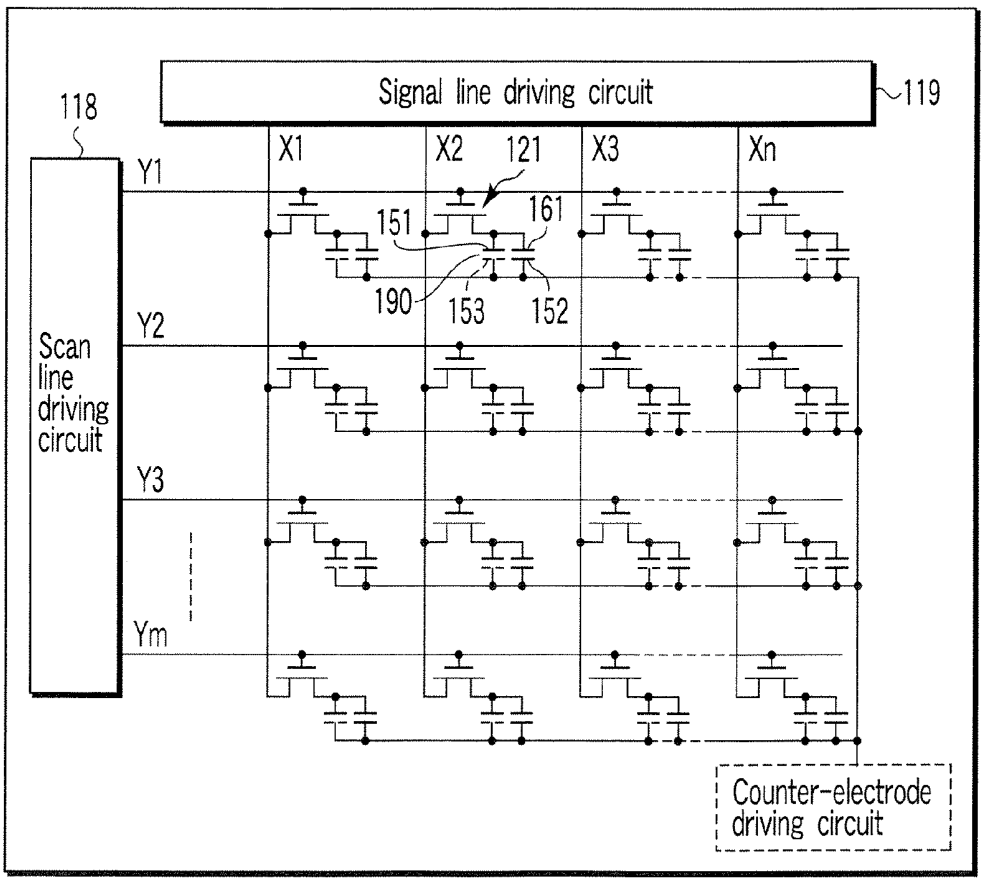

Signal line driving circuit
119
118
X1
X2
121
X3
Xn
Y1
151
161
190
153
152
Y2
Scan line driving circuit
Y3
Ym
Counter-electrode driving circuit

FIG. 2

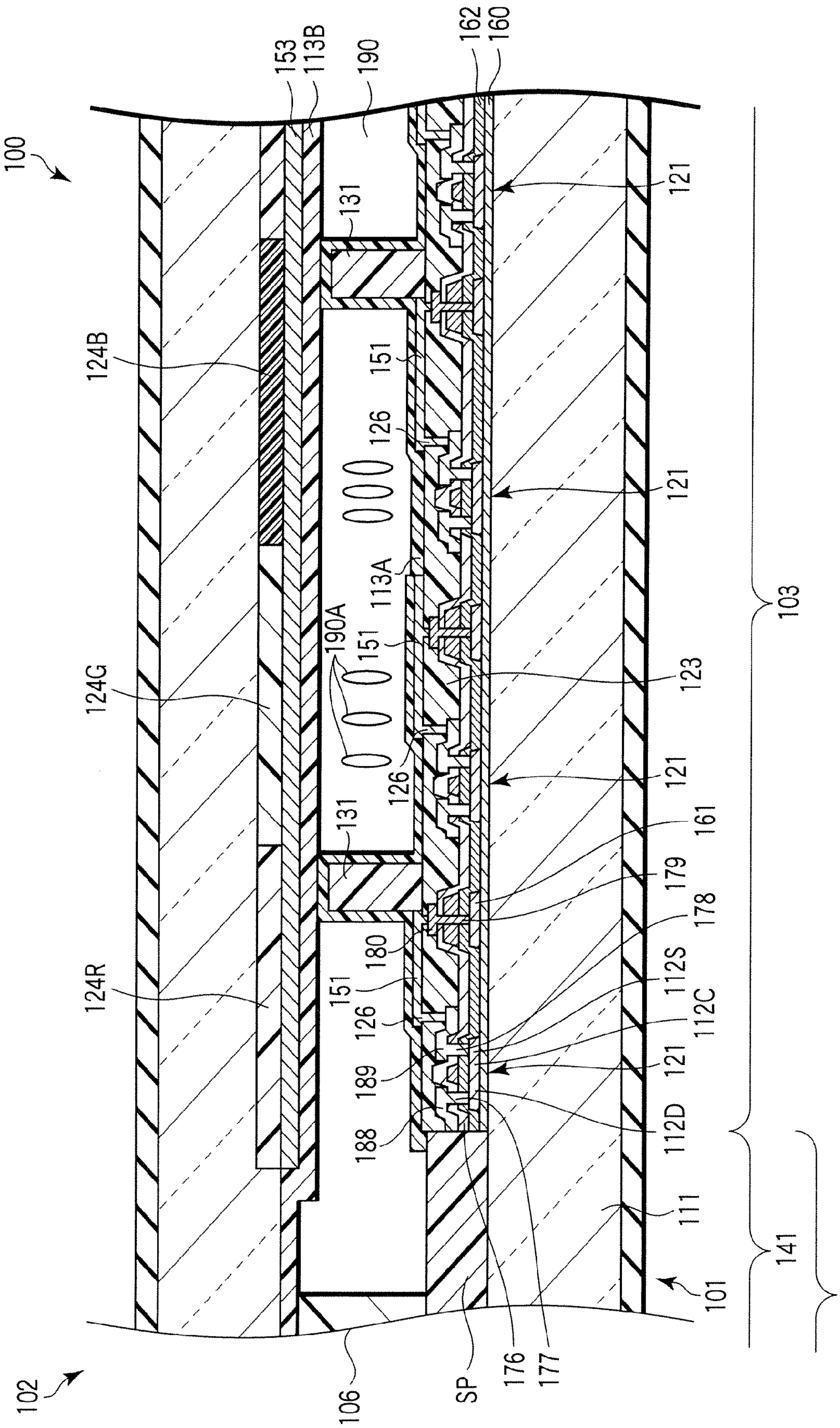

100
102
124B
124G
124R
153
113B
190
162
160
131
151
126
113A
190A
121
123
161
179
178
180
112S
112C
112D
189
188
111
141
101
103
104
106
SP
176
177

FIG. 3

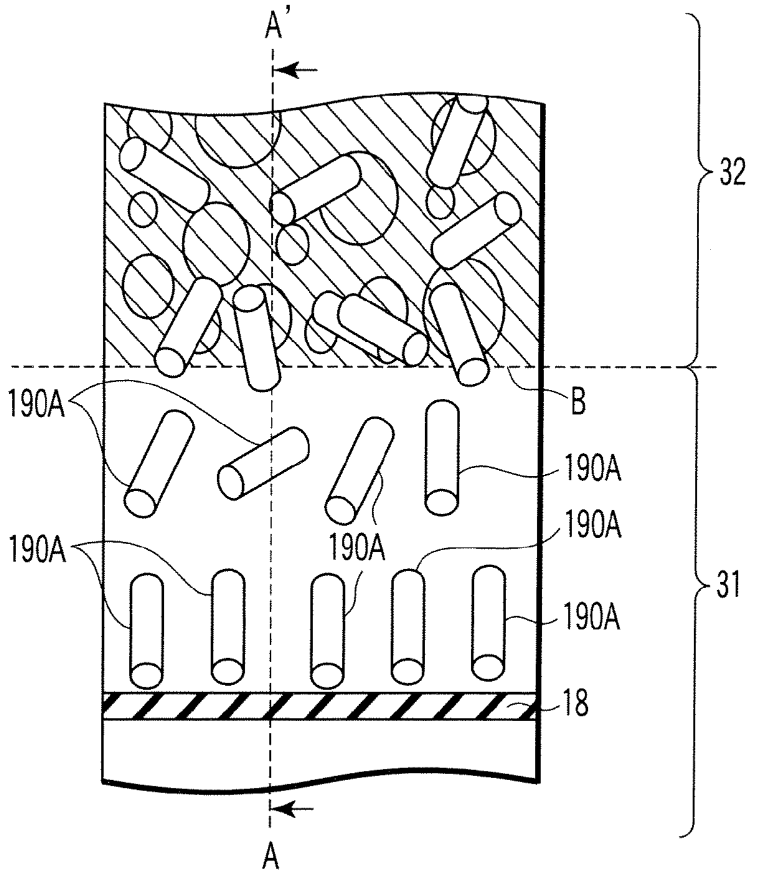

A'
32
B
190A
190A
190A
190A
190A
190A
31
190A
18
A

FIG. 4

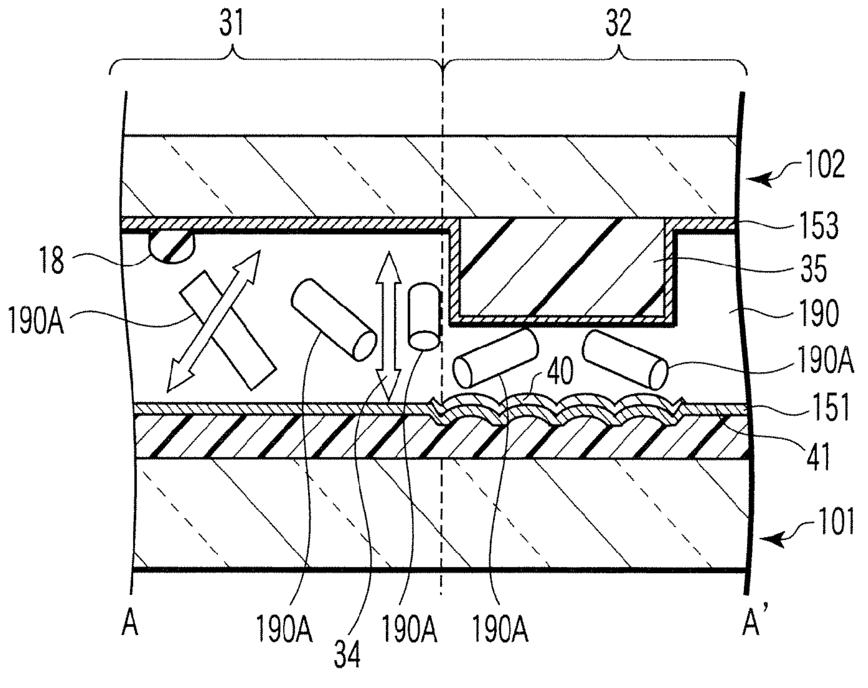

31
32
102
153
18
35
190A
190
190A
40
151
41
101
A
190A
34
190A
190A
A'

FIG. 5

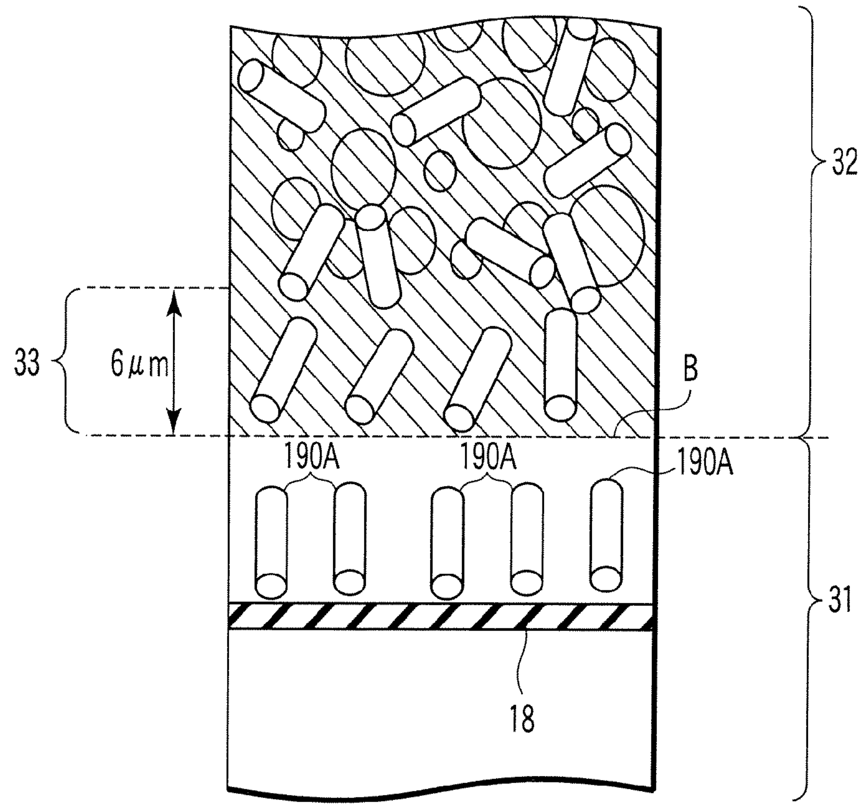

32
33
6μm
B
190A
190A
190A
31
18

FIG. 6

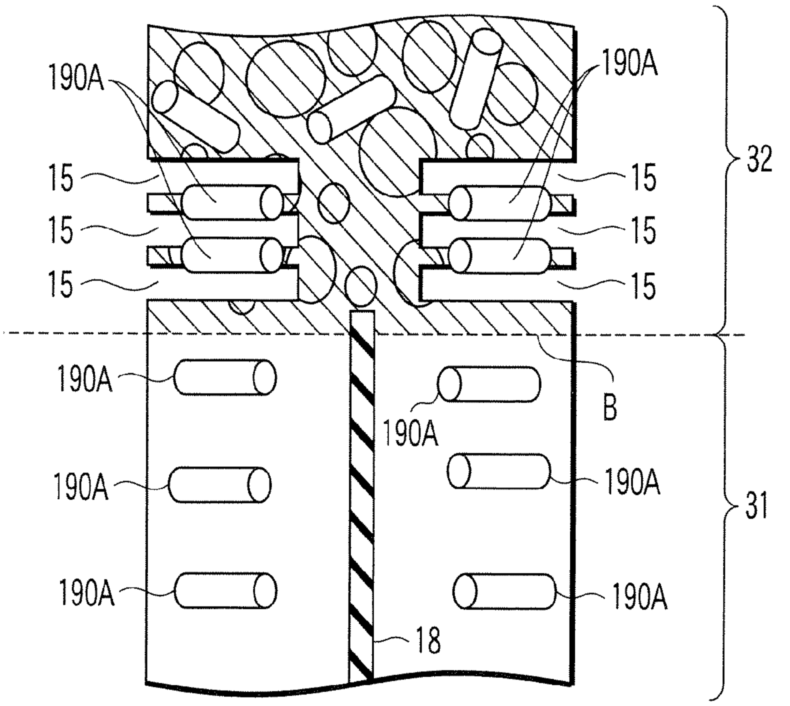

190A
190A
15
15
15
15
15
15
32
190A
190A
B
190A
190A
190A
190A
31
18

FIG. 7

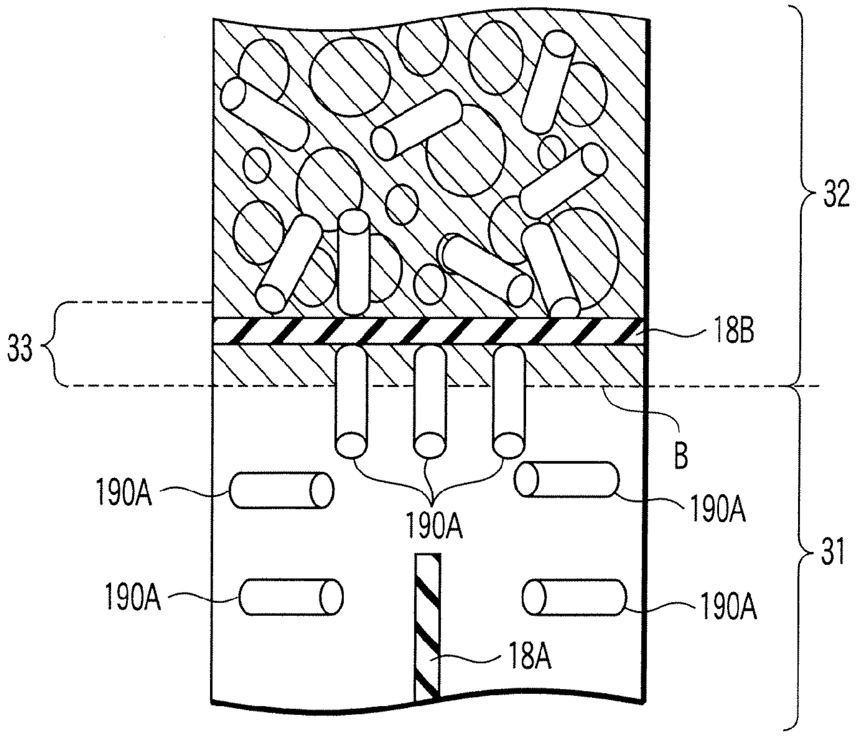

32
33
18B
B
190A
190A
190A
31
190A
190A
18A

FIG. 8

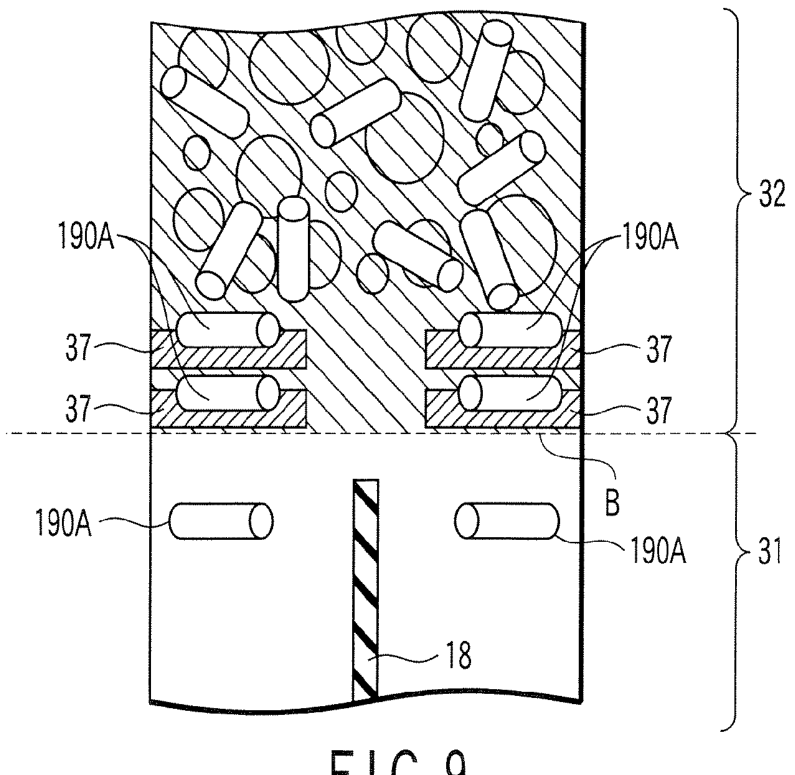

32
190A
190A
37
37
37
37
B
190A
190A
31
18

FIG. 9

	Transmittance	Uniformity in alignment division	Response time *)	Afterimage
Example 1	18%	Good	20ms	None
Example 2	17%	Good	25ms	Slight
Example 3	15%	Good	18ms	None
Example 4	17%	Good	17ms	None
Example 5	18%	Good	20ms	None

*) Sum of time, during which luminance changes from 10% to 90% when minimum gray level is switched to maximum gray level, and time during which luminance changes from 90% to 10% when maximum gray level is switched to minimum gray level

FIG. 10

LIQUID CRYSTAL DISPLAY DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is based upon and claims the benefit of priority from prior Japanese Patent Application No. 2005-245921, filed Aug. 26, 2005, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates generally to a liquid crystal display device, and more particularly to a transflective liquid crystal display device having a reflective display region and a transmissive display region.

[0004] 2. Description of the Related Art

[0005] A display device using a liquid crystal element is not self-luminous, unlike a CRT (Cathode-Ray Tube) or an EL (Electroluminescence) device. As a liquid crystal display device which enables luminous display, there is known a transmissive liquid crystal display device, wherein a backlight is disposed on the back side of the liquid crystal element and the backlight illuminates the back side of the liquid crystal element. In usual cases, however, the backlight consumes more than 50% of the total power which is consumed by the liquid crystal display device. As a liquid crystal display device which can reduce power consumption, there is known a reflective liquid crystal display device, which effects luminous display by using only ambient light, and this reflective liquid crystal display device has been applied to mobile information devices which are, in usual cases, used outdoors or carried by users. A drawback of the reflective liquid crystal display device is that when ambient light is dark, reflective light for effecting display decreases and the visibility considerably deteriorates. On the other hand, the transmissive liquid crystal display device has such a drawback that the visibility deteriorates when ambient light is very bright, for example, in fine weather.

[0006] To solve these problems, there is known a transflective liquid crystal display device wherein a reflective display part and a transmissive display part are separately provided in each of pixels.

[0007] In a dark place, the transflective liquid crystal display device functions as a transmissive liquid crystal display device which displays an image by selectively passing backlight through the transmissive display part in each pixel. In a light place, the transflective liquid crystal display device functions as a reflective liquid crystal display device which displays an image by selectively reflecting ambient light by means of the reflective display part in each of the pixels. Thereby, power consumption can greatly be reduced.

[0008] Various liquid crystal display methods are applicable to the liquid crystal display device, if a variation in liquid crystal alignment is utilized in such methods. For example, a TN (twisted nematic) mode and a STN (super-twisted nematic) mode, in which polarizers are used, are adopted in reflective liquid crystal display devices. In recent years, a phase-transition guest-host (GH) mode, which can realize bright display since no polarizer plate is used, has been developed.

[0009] In a multi-domain VAN (Vertical Alignment Nematic) (MVA) mode, liquid crystal molecules in the vicinity of the surface of an alignment film are vertically aligned by adopting a vertical alignment treatment, and the birefringence index of the liquid crystal layer becomes substantially zero. Thus, black of an adequate level can be displayed and a high contrast can be obtained. In addition, the design for compensating a viewing angle is relatively easy, and a wide viewing angle can be realized. Furthermore, a rubbing alignment treatment process, which has conventionally been considered to be a possible cause of defects, such as electrostatic discharge damage, can be dispensed with. Therefore, the MVA mode has attracted particular attention in these years.

[0010] However, if the MVA mode is applied to the transflective liquid crystal display device, the direction of electric field, which is applied to the liquid crystal layer, and the elastic energy due to the interface shape become complex. It is thus difficult to obtain fixed guidelines relating to the alignment state of liquid crystal molecules in association with the arrangement of ridge-like projections and slits. In some cases, the arrangement of liquid crystal molecules may be disturbed in each domain, and it is difficult to stably form a plurality of domains in one pixel.

[0011] The present invention has been made in consideration of the above-described problems, and the object of the invention is to provide a liquid crystal display device which can have wide viewing-angle characteristics by virtue of stable domain division, can suppress a decrease in light transmissivity due to, e.g. disturbance of the alignment direction of liquid crystal molecules, and can perform transmissive display and reflective display with high display quality.

BRIEF SUMMARY OF THE INVENTION

[0012] According to an aspect of the present invention, there is provided a liquid crystal display device comprising: first and second electrode substrates; a liquid crystal layer which is held between the first and second electrode substrates, and includes a transmissive display part and a reflective display part which neighbor each other via a boundary, an alignment state of liquid crystal molecules in the liquid crystal layer being controlled by an application voltage from the first and second electrode substrates in the transmissive display part and the reflective display part; and control means for making an alignment direction of the liquid crystal molecules, which are present near the boundary in the reflective display part, substantially match an alignment direction of the liquid crystal molecules which are present near the boundary in the transmissive display part.

[0013] The invention can provide a liquid crystal display device which has wide viewing-angle characteristics by virtue of stable domain division, can suppress a decrease in light transmissivity due to, e.g. disturbance of the alignment direction of liquid crystal molecules, and can perform transmissive display and reflective display with high display quality.

[0014] Additional objects and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out hereinafter.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0015] The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention, and together with the general description given above and the detailed description of the embodiments given below, serve to explain the principles of the invention.

[0016] FIG. **1** schematically shows an example of the structure of a liquid crystal display panel which is included in a liquid crystal display device according to an embodiment of the present invention;

[0017] FIG. **2** is a view for describing the example of the structure of the liquid crystal display panel shown in FIG. **1**;

[0018] FIG. **3** is a cross-sectional view for describing the example of the structure of the liquid crystal display panel shown in FIG. **1**;

[0019] FIG. **4** is a view for describing an example of the structure of a pixel in a case where an MVA mode is applied to a transflective liquid crystal display device;

[0020] FIG. **5** is a cross-sectional view taken along line A-A' in FIG. **4**, showing a transmissive display part and a reflective display part;

[0021] FIG. **6** is a view for describing an example of the structure of a pixel in a liquid crystal display device according to Example 1 of the present invention;

[0022] FIG. **7** is a view for describing an example of the structure of a pixel in a liquid crystal display device according to Example 2 of the present invention;

[0023] FIG. **8** is a view for describing an example of the structure of a pixel in a liquid crystal display device according to Example 3 of the present invention;

[0024] FIG. **9** is a view for describing an example of the structure of a pixel in a liquid crystal display device according to Example 4 of the present invention; and

[0025] FIG. **10** is a table showing results of evaluation of the liquid crystal display devices according to Example 1 to Example 4 of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0026] A liquid crystal display device according to an embodiment of the present invention will now be described with reference to the accompanying drawings. The liquid crystal display device according to the embodiment, for instance, an active-matrix liquid crystal display device, includes a liquid crystal display panel **100**.

[0027] The liquid crystal display panel **100**, as shown in FIG. **1**, includes an array substrate **101**, a counter-substrate **102** which is opposed to the array substrate **101**, and a liquid crystal layer **190** which is held between the array substrate **101** and counter-substrate **102**. In the liquid crystal display panel **100**, a display region **103**, which displays an image, is formed within a region surrounded by an outer peripheral seal member **106** by which the array substrate **101** and counter-substrate **102** are attached. A peripheral region **104**, which is provided around the display region **103**, includes a light-blocking region **141** which is formed in a picture-frame shape on the outside of the outer peripheral seal member **106**.

[0028] In the display region **103**, the array substrate **101**, as shown in FIG. **2**, includes an (m×n) number of matrix-arrayed pixel electrodes **151**, an m-number of scan lines Y1 to Ym which are formed in a row direction of the pixel electrodes **151**, an n-number of signal lines X1 to Xn which are formed in a column direction of the pixel electrodes **151**, and n (m×n) number of thin-film transistors, that is, pixel TFTs **121**, which are disposed as switching elements near intersections of the scan lines Y1 to Ym and signal lines X1 to Xn in association with the (m×n) pixel electrodes **151**.

[0029] In the peripheral region **104**, the array substrate **101** includes a scan line driving circuit **118** which drives the scan lines Y1 to Ym, and a signal line driving circuit **119** which drives the signal lines X1 to Xn.

[0030] As is shown in FIG. **3**, in the display region **103**, the array substrate **101** of the liquid crystal display panel **100** includes, on an insulating substrate **111** such as a glass substrate, switching elements, i.e. pixel TFTs **121**, which are formed in association with the matrix-arrayed pixels, an insulation layer **123** which is formed to cover the display region **103** including the TFTs **121**, pixel electrodes **151** which are disposed on the insulation layer **123** in association with the respective pixels, a plurality of columnar spacers **131** which are formed on the insulation layer **123**, and an alignment film **113**A which is formed to cover the entirety of the pixel electrodes **151**. In the peripheral region **104**, the array substrate **101** includes a light-blocking layer SP which is disposed in the light-blocking region **141** of the transparent substrate so as to surround the periphery of the display region **103**.

[0031] The pixel electrodes **151** are formed of a light-transmissive electrically conductive material, such as ITO (Indium Tin Oxide), on the insulation layer **123**. The pixel electrodes **151** are connected to the pixel TFTs **121** via through-holes **126** which penetrate the insulation layer **123**. The pixel TFTs **121** are connected to the associated scan lines extending in the row direction of the pixel electrodes **151** and to the associated signal lines extending in the column direction of the pixel electrodes **151**. Each pixel TFT **121** is turned on by a driving voltage supplied from the scan line, and applies a signal voltage to the associated pixel electrode **151**.

[0032] The array substrate **101** includes the scan lines Y extending in the row direction of the pixel electrodes **151**, the signal lines X extending in the column direction of the pixel electrodes **151**, and the pixel TFTs **121** disposed near the intersections of the scan lines Y and signal lines X in association with the pixel electrodes **151**.

[0033] Further, the array substrate **101** includes a storage capacitance electrode **161** for forming a storage capacitance, which has a potential equal to a potential of the pixel electrode **151** that is disposed to be opposed via a gate insulation film **162**, and also includes a storage capacitance line **152** which is set at a predetermined potential.

[0034] The signal lines X are disposed to be substantially perpendicular to the scan lines Y and storage capacitance lines **152** via an interlayer insulation film **176**. The storage capacitance lines **152** are formed of the same material in the same layer as the scan lines Y, and are formed substantially parallel to the scan lines Y. A part of the storage capacitance line **152** is disposed to be opposed to the storage capacitance electrode **161** via the gate insulation film **162**. The storage capacitance electrode **161** is formed of an impurity-doped polysilicon film.

[0035] The wiring lines, such as the signal lines X, scan lines Y and storage capacitance lines **152**, are formed of a light-blocking low-resistance material such as aluminum or molybdenum-tungsten. In this embodiment, the scan lines Y and storage capacitance lines **152** are formed of molybdenum-tungsten, and the signal lines X are mainly formed of aluminum.

[0036] The pixel TFT **121** includes a semiconductor layer **112** which is formed of a polysilicon film in the same layer as the storage capacitance electrode **161**. The semiconductor layer **112** is disposed on an undercoating layer which is provided on the glass substrate. The semiconductor layer **112** includes a drain region **112**D and a source region **112**S, which are formed by doping impurities on both sides of a channel region **112**C. The pixel TFT **121** includes a gate electrode **163** which is opposed to the semiconductor layer **112** via the gate insulation film **162** and is formed integral with the associated scan line Y.

[0037] A drain electrode **188** of the pixel TFT **121** is formed integral with the signal line X, and electrically connected to the drain region **112**D of the semiconductor layer **112** via a contact hole **177** that penetrates the gate insulation film **162** and interlayer insulation film **176**. A source electrode **189** of the pixel TFT **121** is formed to be electrically connected to the source region **112**S of the semiconductor layer **112** via a contact hole **178** that penetrates the gate insulation film **162** and interlayer insulation film **176**.

[0038] The insulation layer **123** is provided on the interlayer insulation film **176** of the array substrate **101**. The pixel electrodes **151** are provided on the insulation layer **123**. The pixel electrode **151** is electrically connected to the source electrode **189** of the pixel TFT **121** via a through-hole **126**.

[0039] The storage capacitance electrode **161** is electrically connected to a contact electrode **180** which is formed of the same material as the signal line X via a contact hole **179** that penetrates the gate insulation film **162** and interlayer insulation film **176**. Thereby, the source electrode **189** of the pixel TFT **121**, the pixel electrode **151** and the storage capacitance electrode **161** are set at the same potential.

[0040] Besides, as shown in FIG. **3**, the liquid crystal display panel **100** includes the columnar spacers **131** for providing a predetermined gap between the array substrate **101** and opposed substrate **102**. The alignment film **113**A functions to align liquid crystal molecules, which are included in the liquid crystal layer **190**, in a direction substantially vertical to the array substrate **101**.

[0041] The counter-substrate **102** includes color filter layers **124** (R, G, B) which are formed on a transparent insulating substrate **111** such as a glass substrate, a counter-electrode **153**, and an alignment film **113**B which covers the counter-electrode **153**. The counter-electrode **153** is formed of a light-transmissive electrically conductive material, such as ITO, so as to be opposed to all the pixel electrodes **151** on the array substrate **101**. The alignment film **113**B functions to align liquid crystal molecules, which are included in the liquid crystal layer **190**, in a direction substantially vertical to the counter-substrate **102**.

[0042] Next, a description is given of the pixel structure which realizes transmissive display and reflective display in the above-described liquid crystal display device. As is shown in FIG. **4** and FIG. **5**, the liquid crystal layer **190** includes a transmissive display part **31** and a reflective display part **32**. The pixel electrode **151** includes a transmissive electrode **41** which is disposed on the insulation layer **123**, and a reflective electrode **40** which is disposed on that part of the transmissive electrode **41**, which corresponds to the reflective display part **32** of the liquid crystal layer **190**. The reflective electrode **40** has an uneven shape which corresponds to an uneven shape of the surfaces of the insulation layer **123** and transmissive electrode **41** provided on the insulating substrate **111**.

[0043] The reflective electrode **40** is formed of a light-reflective metal material such as aluminum, and reflects light, which is incident on the reflective display part **32** from the counter-substrate **102** side, toward the counter-substrate **102**. The transmissive electrode **41** is formed of a light-transmissive metal material such as ITO.

[0044] Specifically, in the reflective display part **32**, the reflective electrode **40** reflects incident light from the counter-substrate **102** side towards the counter-substrate **102**. In the transmissive display part **31**, the transmissive electrode **41** transmits incident light from the array substrate **101** side toward the counter-substrate **102**. Thereby, the liquid crystal display panel **100** realizes transmissive display and reflective display.

[0045] The counter-substrate **102** includes a transparent resin layer **35**, which makes different the thickness of the liquid crystal layer **190** of the transmissive display part **31** from the thickness of the liquid crystal layer **190** of the reflective display part **32**, under the counter-electrode **153** which is opposed to the reflective display part **32** of the liquid crystal layer **190**. By the transparent resin layer **35**, the thickness of the liquid crystal layer **190** of the reflective display part **32** is reduced to about ½ of the thickness of the liquid crystal layer **190** of the transmissive display part **31**.

[0046] As shown in FIG. **4**, a boundary B between the transmissive display part **31** and reflective display part **32** of the liquid crystal layer **190** extends substantially linearly in a direction which is substantially perpendicular to the longitudinal direction of the pixel electrode **151**. The counter-substrate **102** includes a ridge-shaped projection **18** (dielectric element) functioning as control means for controlling an electric field which is generated in the liquid crystal layer **190**. The ridge-shaped projection **18** is disposed on the counter-electrode **153** which is opposed to the transmissive display part **31** of the liquid crystal layer **190**, and extends substantially in parallel with the boundary B.

[0047] If the ridge-shaped projection **18** is formed as described above, liquid crystal molecules are tilted in a fixed direction so as to align their dielectric anisotropy along lines **34** of electric force which are substantially normal to the substrate. However, in the case where the dielectric anisotropy of the liquid crystal layer **190** is negative, the azimuth direction is not determined by the lines of electric force and the direction of alignment is determined so as to minimize elastic energy of alignment. Thus, the liquid crystal is aligned along grooves of the uneven structure for diffusion reflection. As a result, the liquid crystal molecules **190**A are oriented in various azimuth angles at the boundary B between the reflective display part **32** and transmissive display part **31**, and a region where liquid crystal molecules are not aligned in a desired direction occurs in the transmissive display part **31**.

[0048] On the other hand, the liquid crystal layer **190** can be aligned in the desired direction in the vicinity of the boundary B of the transmissive display part **31** by forming control means for making the alignment direction of liquid crystal molecules **190**A, which are present near the boundary B of the reflective display part **32**, substantially match the alignment direction of liquid crystal molecules **190**A, which are present near the boundary B of the transmissive display part **31**.

[0049] Specifically, no orientational relaxation occurs near the boundary B between the reflective display part **32** and transmissive display part **31** if the alignment direction of liquid crystal molecules **190**A in the reflective display part **32** near the boundary B is made to match the alignment direction of liquid crystal molecules **190**A in the transmissive display part **31** near the boundary B.

[0050] Hence, according to the present embodiment, it is possible to provide a liquid crystal display device which can have wide viewing-angle characteristics by virtue of stable domain division, can suppress a decrease in light transmissivity due to, e.g. disturbance of the alignment direction of liquid crystal molecules **190**A, and can perform transmissive display and reflective display with high display quality.

[0051] Next, preferred examples of the present invention will be described. In a liquid crystal display device according to Example 1 of the invention, as shown in FIG. **6**, the counter-substrate **102** has a transparent resin layer **35**, which varies the thickness of the liquid crystal layer, under the counter-electrode **153** which is opposed to the transmissive display part **31** of the liquid crystal layer **190**. In this Example 1, the thickness of the transparent resin layer **35** is about 1.8 μm.

[0052] The array substrate **101**, as shown in FIG. **6**, includes, as control means, a planar region **33** of the pixel electrode **151** near the boundary B of the reflective display part **32**. The planar region **33** of the pixel electrode **151** is provided in a range of 6 μm from the boundary B in the reflective display part **32**.

[0053] The counter-substrate **102** includes, on the counter-electrode **153** opposed to the transmissive display part **31**, a ridge-shaped projection **18** which extends substantially in parallel to the boundary B. In this Example 1, the thickness of the ridge-shaped projection **18** is about 1.2 μm.

[0054] The liquid crystal display panel **100** is formed by using the counter-substrate **102** and array substrate **101**. An alignment film (not shown) with a thickness of 70 nm, which exhibits vertical alignment properties, was coated on the counter-substrate **102** which is opposed to the array substrate **101**. Resin beads each with a diameter of 3.8 μm were used as spacers (not shown) between the array substrate **101** and counter-substrate **102**. A liquid crystal material with negative dielectric anisotropy was filled in the space that is defined by the spacers between the array substrate **101** and the counter-substrate **102**. Thus, a liquid crystal display panel **100** capable of effecting reflective display and transmissive display was formed.

[0055] According to the liquid crystal display device of Example 1, in the uneven structure region for diffusion reflection which is provided in the reflective display part **32**, the liquid crystal molecules **190**A are oriented in various directions by the excluded volume effect so as to be aligned in parallel to the grooves of the uneven structure. On the other hand, in the planar region **33** of the reflective display part **32** which is located on the transmissive display part **31** side, local deformation of the liquid crystal layer **190** relaxes so as to become minimum since the elastic energy is large, and the liquid crystal layer **190** tries to be aligned in one direction. Accordingly, the liquid crystal molecules **190**A in the planar region **33** are aligned in a direction which is not contradictory to the alignment direction in the neighboring transmissive display part **31**.

[0056] In particular, in order to relax local deformation, the planar region **33** with a size of about 6 μm is necessary. Thus, it should suffice if the planar region **33** with a size of about 6 μm or more, from the end of the transmissive display part **31**, is provided. However, if importance is placed on the transmissive display, it is preferable to provide the planar region **33** with a size of about 10 μm. As a result, the liquid crystal can substantially be aligned in a desired direction in the transmissive display part **31**.

[0057] Therefore, according to Example 1, it is possible to provide a liquid crystal display device which can have wide viewing-angle characteristics by virtue of stable domain division, can suppress a decrease in light transmissivity due to, e.g. disturbance of the alignment direction of liquid crystal molecules **190**A, and can perform transmissive display and reflective display with high display quality.

[0058] A liquid crystal display device according to the above-described Example 1 was experimentally manufactured. FIG. **10** shows an evaluation result of transmittance and response time of the manufactured liquid crystal display device.

[0059] A liquid crystal display device according to Example 2 of the invention is described. As shown in FIG. **7**, the array substrate **101** includes, as control means, slit parts **15** which are missing parts of the pixel electrode **151**. In the reflective display part **32**, the slit parts are formed at end sides extending substantially perpendicular to the boundary B and are arranged in stripes extending substantially in parallel to the boundary B.

[0060] The counter-substrate **102** includes, on the counter-electrode opposed to the transmissive display part **31**, a ridge-shaped projection **18** which extends substantially perpendicular to the boundary B.

[0061] The structure of the liquid crystal display panel **100** of this Example 2 is the same as that of the liquid crystal display panel **100** of Example 1, except for the above-described pixel electrode **151** and the ridge-shaped projection **18** on the counter-electrode **153**. In Example 2, the same advantageous effect as in Example 1 can be obtained. In the case where the slit parts **15** are used as control means, the slit parts **15**, which are missing parts of the electrode, can be designed relatively freely within the pixel. Thereby, the preferable transmittance, response speed and viewing angle of the liquid crystal display device can be obtained relatively easily.

[0062] FIG. **10** shows an evaluation result of transmittance and response time of the liquid crystal display device including the above-described liquid crystal display panel **100**.

[0063] A liquid crystal display device according to Example 3 of the invention is described. As shown in FIG. **8**, the counter-substrate **102** includes, as control means, a first ridge-shaped projection **18**A and a second ridge-shaped projection **18**B, which are provided, respectively, on the counter-electrode **153** opposed to the transmissive display part **31** and the counter-electrode **153** opposed to the reflective display part **32**.

[0064] The first ridge-shaped projection **18**A, which is provided on the counter-electrode **153** opposed to the transmissive display part **31**, extends in a direction substantially perpendicular to the boundary B. The second ridge-shaped projection **18**B, which is provided on the counter-electrode **153** opposed to the reflective display part **32**, extends substantially in parallel to the boundary B.

[0065] By arranging the first ridge-shaped projection **18**A and second ridge-shaped projection **18**B as described above, liquid crystal molecules **190**A near the boundary B are aligned substantially perpendicular to the second ridge-shaped projection **18**B. Specifically, according to the liquid crystal display device of Example 3, the alignment direction of liquid crystal molecules **190**A near the boundary B can be made substantially equal between the transmissive display part **31** and reflective display part **32**.

[0066] The structure of the liquid crystal display panel **100** of this Example 3 is the same as that of the liquid crystal display panel **100** of Example 1, except for the above-described pixel electrode **151** and the counter-electrode **153**. In Example 3, the same advantageous effect as in Example 1 can be obtained. FIG. **10** shows an evaluation result of transmittance and response time of a manufactured liquid crystal display device which was experimentally manufactured by using the above-described liquid crystal display panel **100**.

[0067] A liquid crystal display device according to Example 4 of the invention is described. As shown in FIG. **9**, the array substrate **101** includes, as control means, stripe-shaped recess parts **37** which are formed on the pixel electrode **151**. The recess parts **37** extend, in the reflective display part **32**, substantially in parallel to the boundary B from end sides of the pixel electrode **151** which are substantially perpendicular to the boundary B between the transmissive display part **31** and reflective display part **32**.

[0068] The recess parts **37** depend on the unevenness on the insulation layer **123**, which is disposed as the underlayer of the pixel electrode **151**. Specifically, the recess parts **37** are formed by disposing the pixel electrode **151** on the unevenness of the insulation layer **123** which is the underlayer of the pixel electrode **151**. Preferably, the unevenness of the insulation layer **123** should be formed in the reflective display part **32** at the same time in the same process as the formation of the uneven structure for diffusion-reflecting the incident light from the counter-substrate **102** side. Thereby, the liquid crystal display panel **100** can be formed without increasing the number of fabrication steps.

[0069] Usable materials of the insulation layer **123** include an acrylic resin, an epoxy resin and a novolak resin. By forming the recess portions **37** at the same time as the uneven structure, it becomes possible to provide, without increasing the number of fabrication steps, a liquid crystal display device which can have wide viewing-angle characteristics by virtue of stable domain division, can suppress a decrease in light transmissivity due to, e.g. disturbance of the alignment direction of liquid crystal molecules **190**A, and can perform transmissive display and reflective display with high display quality.

[0070] The counter-substrate **102** includes, on the counter-electrode **153** opposed to the transmissive display part **31**, a ridge-shaped projection **18** which extends in a direction substantially perpendicular to the boundary B.

[0071] By disposing the recess portions **37** and ridge-shaped projection **18** as described above, liquid crystal molecules **190**A of the reflective display part **32** and transmissive display part **31** in the vicinity of the boundary B are aligned substantially in parallel to the boundary B. In short, in the vicinity of the boundary B, the alignment directions of liquid crystal molecules **190**A of the transmissive display part **31** and reflective display part **32** can be made to agree with each other.

[0072] The structure of the liquid crystal display panel **100** of this Example 4 is the same as that of the liquid crystal display panel **100** of Example 1, except for the above-described pixel electrode **151** and the counter-electrode **153**. In Example 4, the same advantageous effect as in Example 1 can be obtained. FIG. **10** shows an evaluation result of transmittance and response time of a liquid crystal display device which was experimentally manufactured by using the above-described liquid crystal display panel **100**.

[0073] As shown in FIG. **10**, according to the invention, it is possible to provide a liquid crystal display device which has wide viewing-angle characteristics by virtue of stable domain division, has less factors of decrease in light transmittance, such as disturbance of the alignment state of liquid crystal molecules **190**A, and can perform transmissive display and reflective display with high display quality.

[0074] As has been described above in detail, in the transflective liquid crystal display device, the control means for making the alignment direction of liquid crystal molecules **190**A, which are present in the transmissive display part **31** side region of the reflective display part **32**, match the alignment direction of liquid crystal molecules **190**A in the reflective display part **32** side region of the transmissive display part **31**, is disposed in the transmissive display part **31** side region of the reflective display part **32**. Thereby, the liquid crystal display device, which can effect transmissive display and reflective display with high display quality, can be provided.

[0075] The present invention is not limited directly to the above-described embodiments. In practice, the structural elements can be modified without departing from the spirit of the invention.

[0076] For example, by patterning and disposing a dielectric material on the pixel electrode **151**, the alignment direction of liquid crystal molecules **190**A, which are present in the transmissive display part **31** side region of the reflective display part **32**, can be made to match the alignment direction of liquid crystal molecules **190**A in the reflective display part **32** side region of the transmissive display part **31**.

[**0077**] In this case, for example, dielectric elements, which extend substantially in parallel to the boundary B from end sides that are substantially perpendicular to the boundary B, are disposed near the boundary B of the reflective display part **32**. A ridge-shaped projection **18**, which extends in a direction substantially perpendicular to the boundary B, is disposed on the counter-substrate **102** in the transmissive display part **31**. Thereby, the liquid crystal molecules **190** are aligned substantially in parallel to the boundary B in the vicinity of the boundary B between the transmissive display part **31** and reflective display part **32**, and the same advantages as in the above-described Examples can be obtained.

[**0078**] Examples of usable dielectric materials include an acrylic resin, an epoxy resin and a novolak resin, which exhibit a lower dielectric constant than the liquid crystal material. In particular, in the design with importance placed on the transmittance of the liquid crystal layer, it is preferable to use a resin material which can be subjected to microfabrication processes.

[**0079**] In the above-described embodiment, only the alignment films **113** are disposed on the pixel electrodes **151** and counter-electrode **153**. However, depending on structures, insulation films may be disposed on these electrodes according to purposes of use. In this case, the insulation film may be formed of, e.g. an inorganic thin film of SiO_2, SiN_x, Al_2O_3, etc., or an organic thin film of polyimide, photoresist resin, high-polymer liquid crystal, etc.

[**0080**] In the case where the insulation film is an inorganic thin film, the insulation film may be formed of evaporation deposition, sputtering, CVD (Chemical Vapor Deposition) or solution coating. In the case where the insulation film is an organic thin film, a solution of organic substance or a precursor solution thereof may be coated by spinner coating, screen print coating or roll coating, and the coated film may be cured under predetermined curing conditions (e.g. heating, light radiation). Alternatively, the organic thin film may be formed by evaporation deposition, sputtering, CVD, or a LB (Langmuir-Blodgett) process.

[**0081**] The pixel TFT **121** may be formed by stacking a semiconductor layer of, e.g. a-Si, p-Si or ITO, and a metal layer of, e.g. Al, Mo, Cr, Cu or Ta. The intense/weak region of electric field, which functions as means for controlling the tilt of the liquid crystal molecules **190**A may be formed by using ITO for forming the pixel electrode **151**, or a metal wiring line (Al, Mo, Cu) for applying a signal voltage.

[**0082**] As regards the mode of liquid crystal, it is possible to use a liquid crystal with positive dielectric anisotropy. However, in order to effectively control the alignment direction and tilt direction by the magnitude (intense/weak) of electric field, it is most desirable to use a VAN mode in which a liquid crystal with negative dielectric anisotropy is vertically aligned. In particular, in a display device with importance placed on contrast, it is possible to design a screen with a high contrast of 500:1 or more and with a high brightness by high-transmittance design, by combining the VAN-mode normally-black setting and the orientation division state of the present invention.

[**0083**] Various inventions can be made by properly combining the structural elements disclosed in the embodiments. For example, some structural elements may be omitted from all the structural elements disclosed in the embodiments. Furthermore, structural elements in different embodiments may properly be combined.

[**0084**] For example, in the above-described embodiment and Example 2, the ridge-shaped projection **18** of the counter-substrate **102** and the slit parts **15** are provided as the control means. Alternatively, the ridge-shaped projection **18** of the counter-substrate **102** may be combined with other structural elements. The combination of the ridge-shaped projection **18** and the dielectric element on the pixel electrode **151** may be used as the control means. In these cases, too, the same advantageous effects as in the embodiment and Examples can be obtained.

[**0085**] In the above-described Example 2, the slit parts **15** are formed in the region where the uneven structure of the reflective display part **32** is disposed. Alternatively, the slit parts **15** may be disposed on the planar region **33** in Example 1. Thereby, it is possible to more effectively control the alignment direction of the liquid crystal molecules **190**A in the vicinity of the boundary B in the reflective display part **32**.

[**0086**] Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

What is claimed is:

1. A liquid crystal display device comprising:

first and second electrode substrates;

a liquid crystal layer which is held between the first and second electrode substrates, and includes a transmissive display part and a reflective display part which neighbor each other via a boundary, an alignment state of liquid crystal molecules in the liquid crystal layer being controlled by an application voltage from the first and second electrode substrates in the transmissive display part and the reflective display part; and

control means for making an alignment direction of the liquid crystal molecules, which are present near the boundary in the reflective display part, substantially match an alignment direction of the liquid crystal molecules which are present near the boundary in the transmissive display part.

2. The liquid crystal display device according to claim 1, wherein the first electrode substrate includes pixel electrodes which are formed in association with the transmissive display part and the reflective display part, and

the second electrode substrate includes a counter-electrode which is opposed to the pixel electrodes.

3. The liquid crystal display device according to claim 2, wherein the control means is composed of a planar region which is provided on the pixel electrode in the reflective display part in the vicinity of the boundary.

4. The liquid crystal display device according to claim 2, wherein the control means is composed of a missing part which is provided on the pixel electrode in the reflective display part in the vicinity of the boundary.

5. The liquid crystal display device according to claim 2, wherein the control means is composed of a dielectric element which is provided on the counter-electrode in at least one of the transmissive display part and the reflective display part in the vicinity of the boundary.

6. The liquid crystal display device according to claim 2, wherein the control means is composed of a recess part which is provided on the pixel electrode in the reflective display part in the vicinity of the boundary.

7. The liquid crystal display device according to claim 6, wherein the recess part on the pixel electrode depends on unevenness of an insulation layer which is disposed as an underlayer of the pixel electrode.

8. The liquid crystal display device according to claim 1, wherein the liquid crystal layer includes a liquid crystal material with negative dielectric anisotropy.

9. The liquid crystal display device according to claim 8, wherein the first and second electrode substrates include a pair of alignment films having vertical alignment properties with respect to the liquid crystal material.

10. The liquid crystal display device according to claim 1, wherein the control means deforms an electric-field perpendicular to the substrates.

11. The liquid crystal display device according to claim 10, wherein the control means is composed of a planar region which is provided on the pixel electrode in the reflective display part in the vicinity of the boundary.

12. The liquid crystal display device according to claim 10, wherein the control means is composed of a missing part which is provided on the pixel electrode in the reflective display part in the vicinity of the boundary.

13. The liquid crystal display device according to claim 10, wherein the control means is composed of a dielectric element which is provided on the counter-electrode in at least one of the transmissive display part and the reflective display part in the vicinity of the boundary.

14. The liquid crystal display device according to claim 10, wherein the control means is composed of a recess part which is provided on the pixel electrode in the reflective display part in the vicinity of the boundary.

* * * * *

patsnap

专利名称(译)	液晶显示装置		
公开(公告)号	[US20070046886A1](US20070046886A1)	公开(公告)日	2007-03-01
申请号	US11/466230	申请日	2006-08-22
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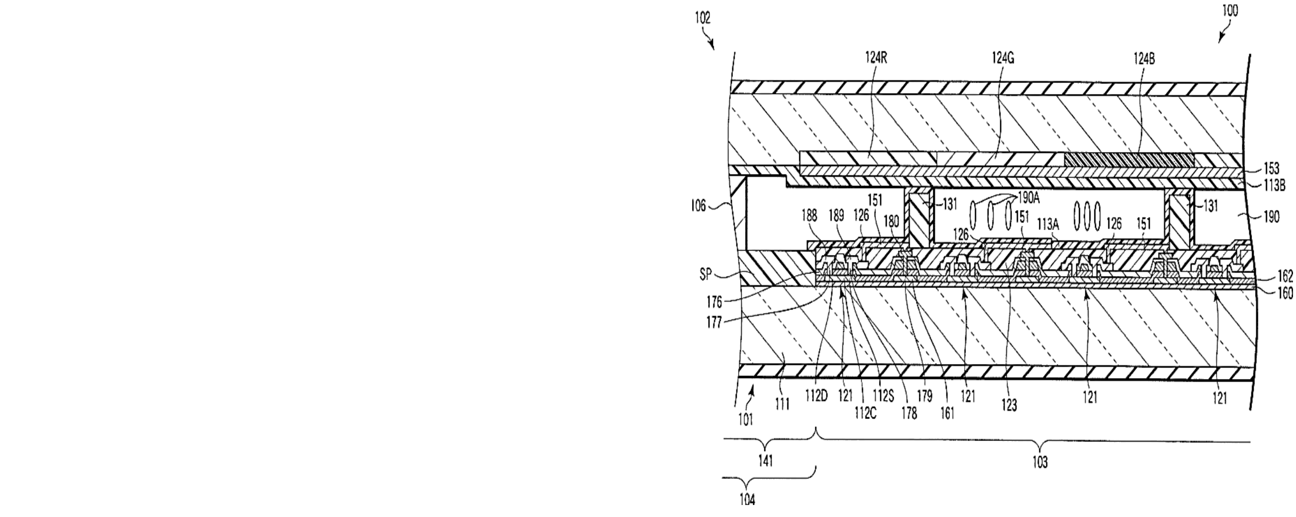
外部链接	Espacenet USPTO		

摘要(译)

一种液晶显示装置，包括阵列基板和对置基板，液晶层，其保持在阵列基板和对置基板之间，并且包括透射显示部分和反射显示部分，它们通过边界彼此相邻，液晶层中的液晶分子的取向状态由来自透射显示部分和反射显示部分中的阵列基板和反基板的施加电压控制，以及用于产生液晶分子的取向方向的控制装置，在反射显示部分中的边界附近存在的，基本上匹配在透射显示部分中的边界附近存在的液晶分子的取向方向。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100
124R
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124B
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113B
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189
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126
151
SP
162
160
176
177
101
111
112D
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112C
112S
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179
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123
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103
104