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(54) LATERAL ELECTRIC FIELD TYPE LIQUID-CRYSTAL DISPLAY DEVICE

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(52) **U.S. Cl.** **349/141**

(57) **ABSTRACT**

A lateral electric field type liquid crystal display device prevents the generation of the reverse rotation domain when the reverse-rotation domain preventing structure using the floating electrodes is adopted. A first liquid-crystal driving electrode (e.g., pixel electrode) and a second liquid-crystal driving electrode (e.g., common electrode) comprise comb-tooth-like parts extending approximately parallel to each other and being meshed with each other, respectively, in a region where images are displayed by applying a liquid-crystal driving electric field to liquid crystal. An electrically isolated first floating electrode is provided in the vicinity of the top end of the comb-tooth-like part of the first liquid-crystal driving electrode, where the first floating electrode comprises an overlapped part which is overlapped with the top end by way of an insulating film. The capacitance intervening between the first floating electrode and the first liquid-crystal driving electrode is greater than the capacitance intervening between the first floating electrode and the second liquid-crystal driving electrode.

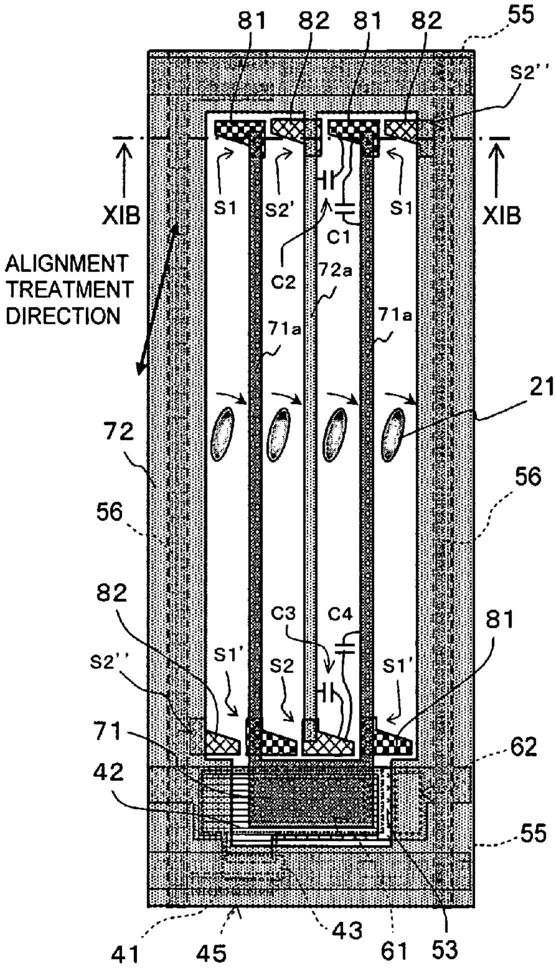
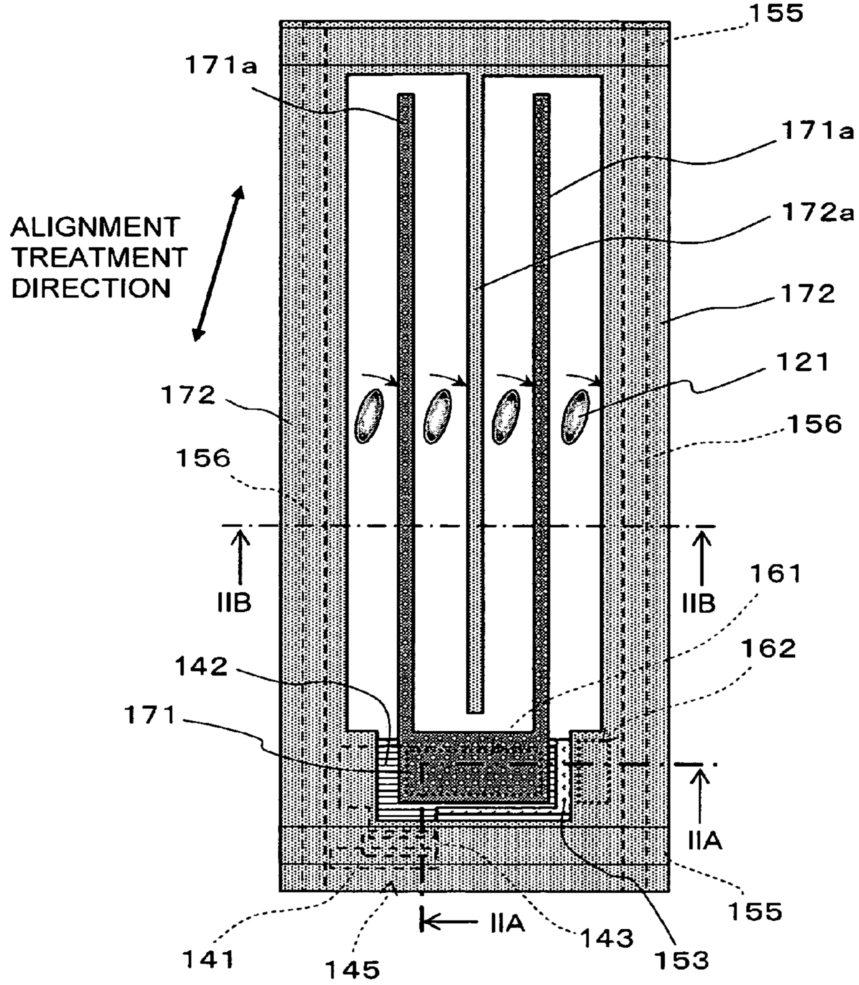
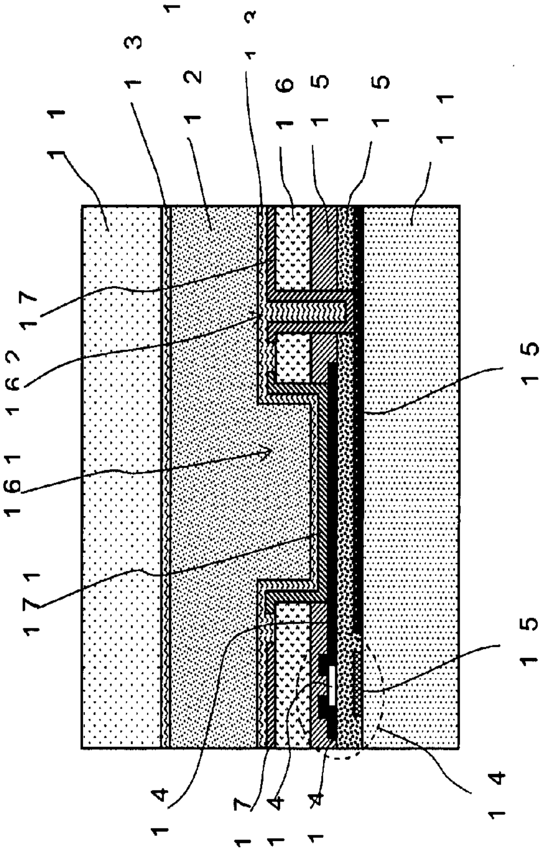


FIG. 1 PRIOR ART



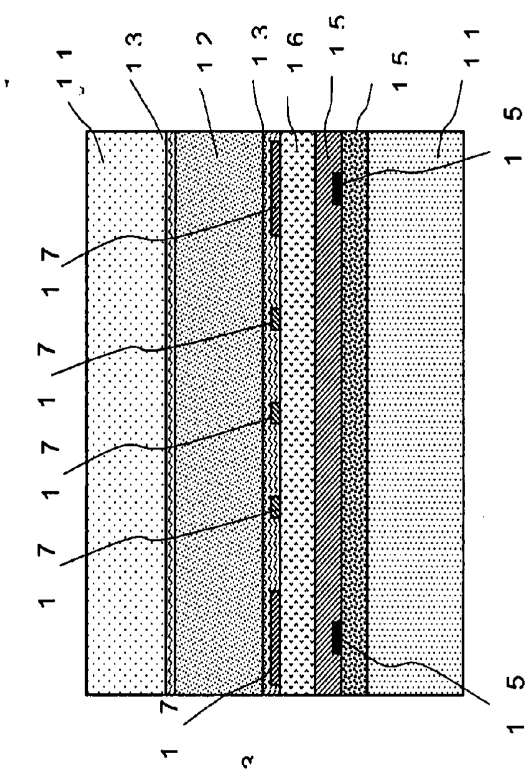
121 ··· LIQUID CRYSTAL MOLECULE
141 ··· DRAIN ELECTRODE
142 ··· SOURCE ELECTRODE
143 ··· SEMICONDUCTOR FILM
145 ··· THIN-FILM TRANSISTOR
153 ··· COMMON BUS LINE
155 ··· GATE BUS LINE
156 ··· DRAIN BUS LINE
161, 162 ··· CONTACT HOLE
171 ··· PIXEL ELECTRODE
172 ··· COMMON ELECTRODE
171a ··· COMB-TOOTH-LIKE PART
172a ··· COMB-TOOTH-LIKE PART

FIG. 2A PRIOR



111, 112 . . . GLASS PLATE
120 . . . LIQUID CRYSTAL
131, 132 . . . ALIGNMENT FILM
141 . . . DRAIN ELECTRODE
142 . . . SOURCE ELECTRODE
143 . . . SEMICONDUCTOR FILM
145 . . . THIN-FILM TRANSISTOR
153 . . . COMMON BUS LINE

FIG. 2B PRIOR



156 . . . DRAIN BUS LINE
157 . . . INTERLAYER INSULATING FILM
159 . . . PROTECTIVE INSULATING FILM
160 . . . ORGANIC INTERLAYER FILM
161, 162 . . . CONTACT HOLE
171 . . . PIXEL ELECTRODE
171a . . . COMB-TOOTH-LIKE PART
172 . . . COMMON ELECTRODE

141 . . . DRAIN ELECTRODE
142 . . . SOURCE ELECTRODE
143 . . . SEMICONDUCTOR FILM
145 . . . THIN-FILM TRANSISTOR
153 . . . COMMON BUS LINE
155 . . . GATE BUS LINE

FIG. 3B PRIOR

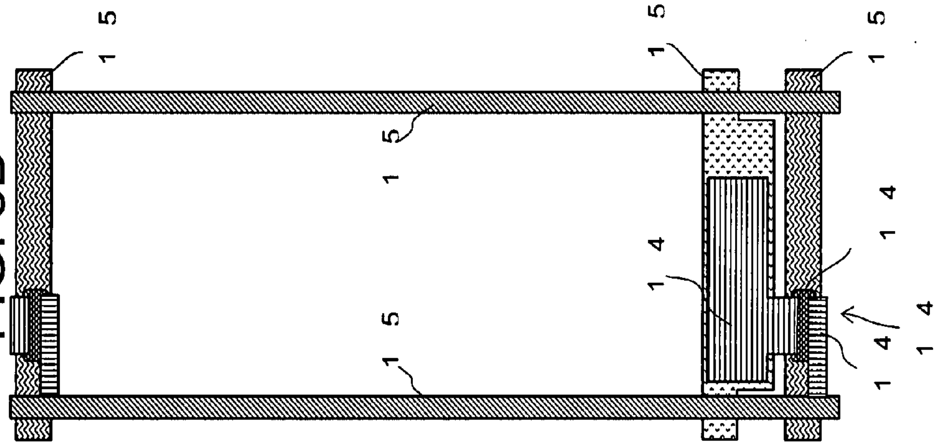
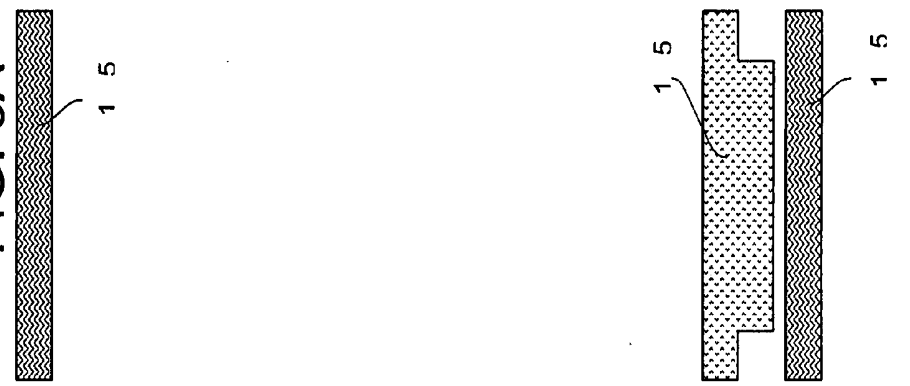


FIG. 3A PRIOR



141 ... DRAIN ELECTRODE
142 ... SOURCE ELECTRODE
143 ... SEMICONDUCTOR FILM
145 ... THIN-FILM TRANSISTOR
153 ... COMMON BUS LINE
161, 162 ... CONTACT HOLE
156 ... DRAIN BUS LINE
171 ... PIXEL ELECTRODE
171a ... COMB-TOOTH-LIKE PART
172 ... COMMON ELECTRODE
172a ... COMB-TOOTH-LIKE PART

FIG. 4B PRIOR

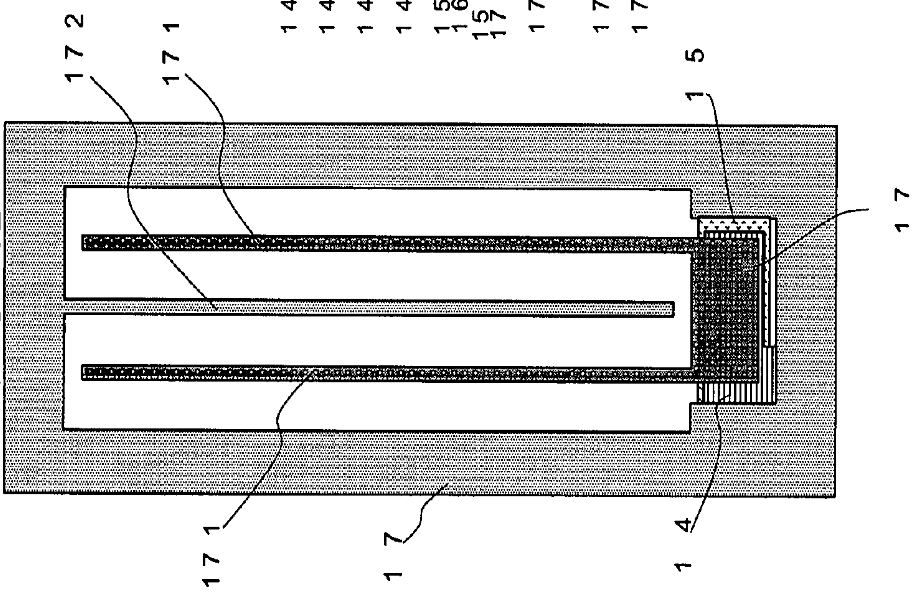


FIG. 4A PRIOR

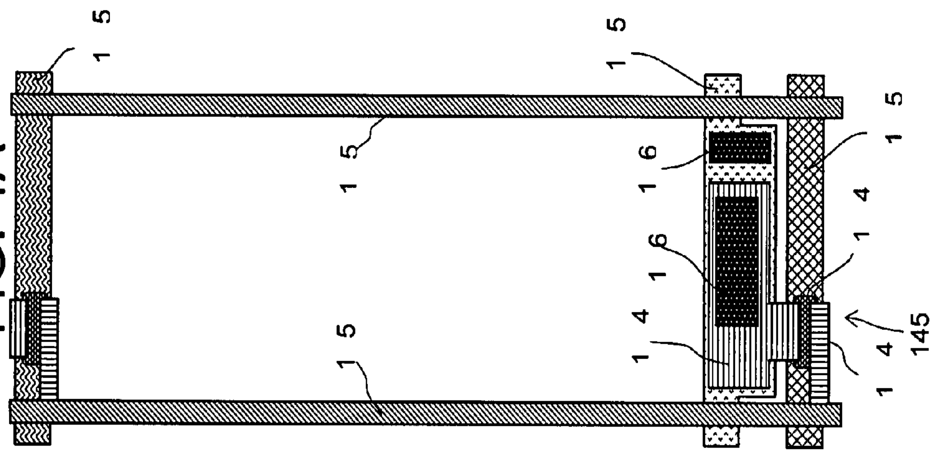


FIG. 5 PRIOR

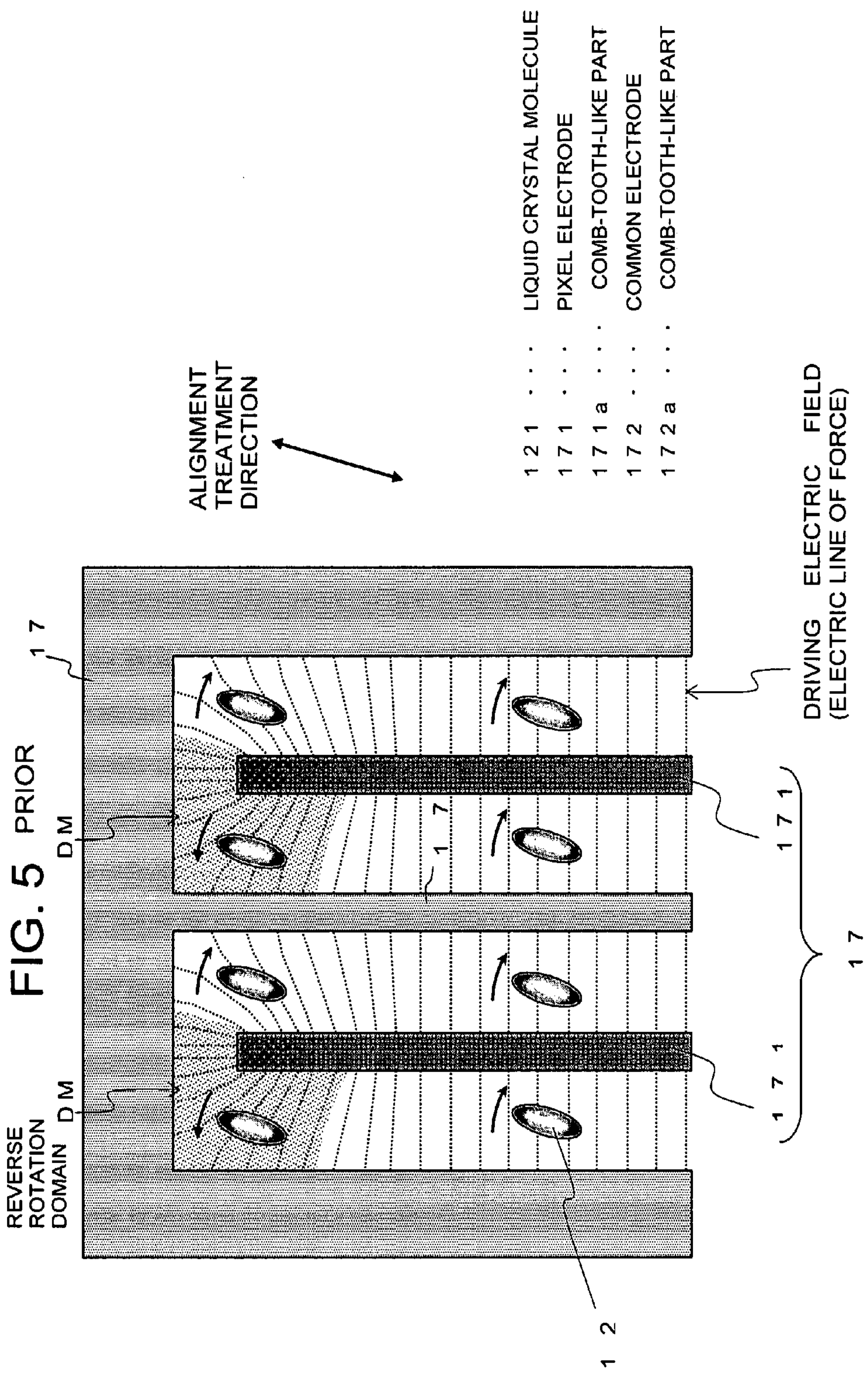

REVERSE ROTATION DOMAIN
DM
DM
17
17
171
171
17
12
ALIGNMENT TREATMENT DIRECTION
DRIVING ELECTRIC FIELD (ELECTRIC LINE OF FORCE)
121 . . . LIQUID CRYSTAL MOLECULE
171 . . . PIXEL ELECTRODE
171a . . . COMB-TOOTH-LIKE PART
172 . . . COMMON ELECTRODE
172a . . . COMB-TOOTH-LIKE PART

FIG. 6 PRIOR

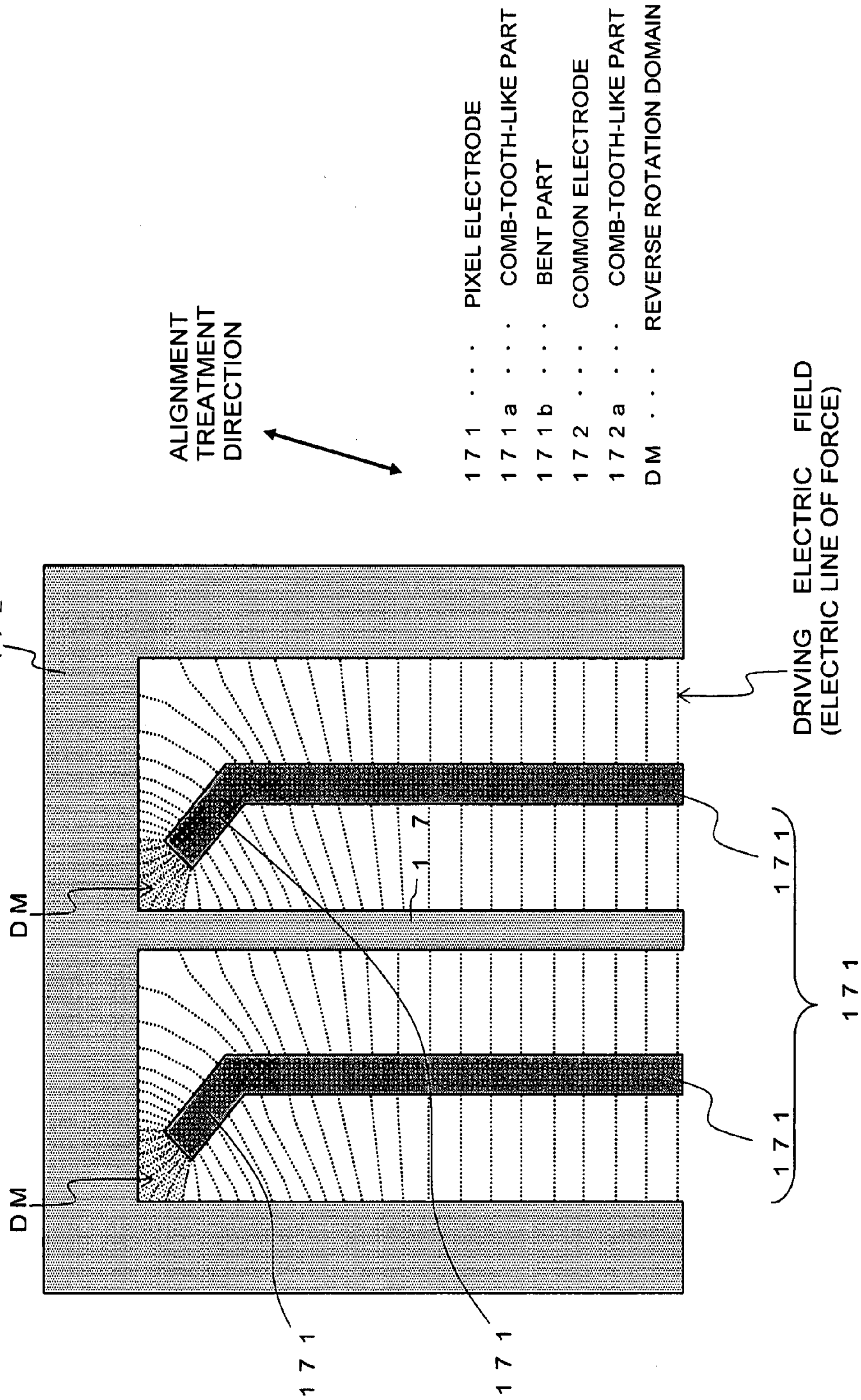

ALIGNMENT TREATMENT DIRECTION
171 . . . PIXEL ELECTRODE
171a . . . COMB-TOOTH-LIKE PART
171b . . . BENT PART
172 . . . COMMON ELECTRODE
172a . . . COMB-TOOTH-LIKE PART
DM . . . REVERSE ROTATION DOMAIN
DRIVING ELECTRIC FIELD
(ELECTRIC LINE OF FORCE)
172
DM
DM
17
171
171
171
171
171

FIG. 7 PRIOR

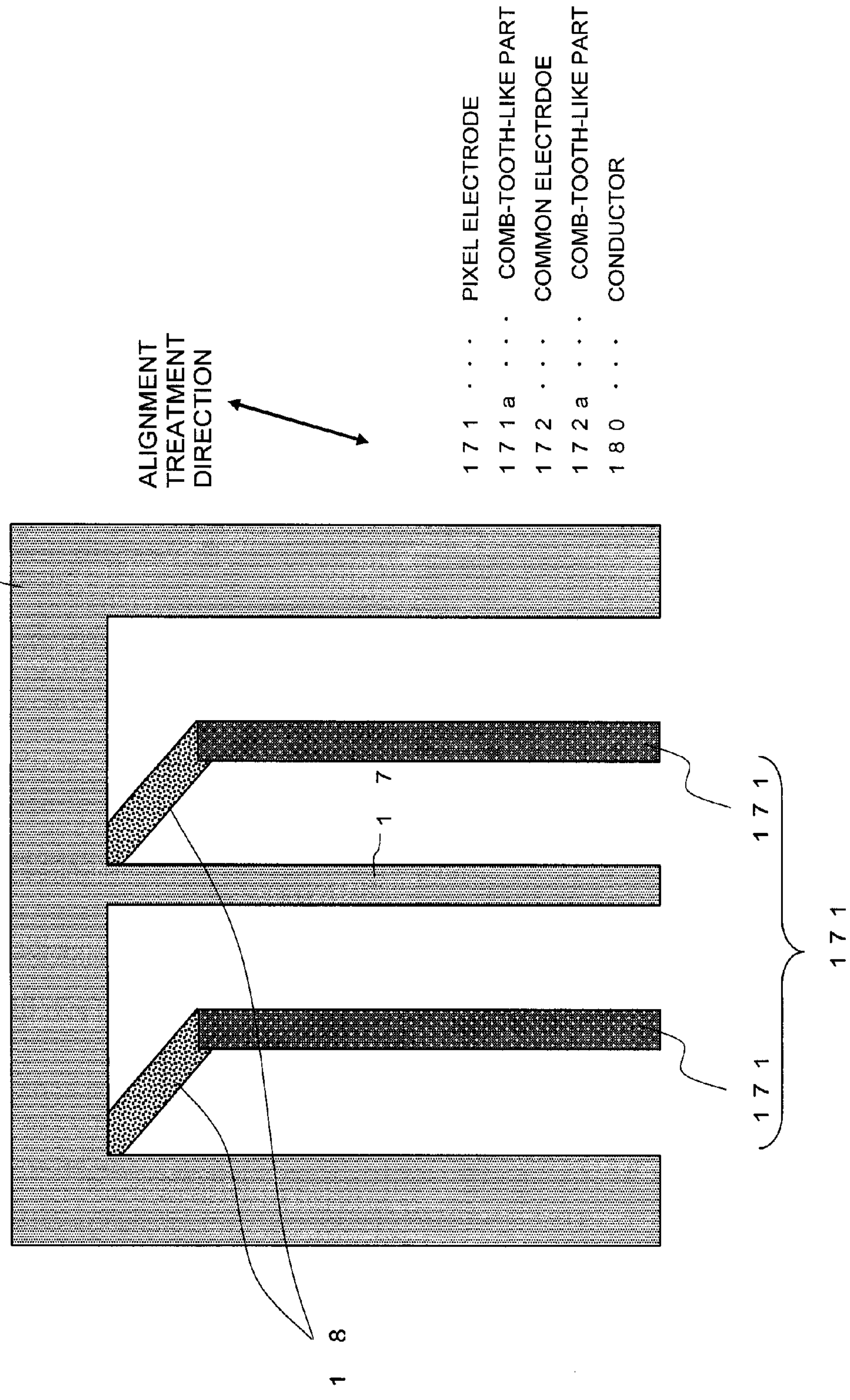

ALIGNMENT TREATMENT DIRECTION
171 . . . PIXEL ELECTRODE
171a . . . COMB-TOOTH-LIKE PART
172 . . . COMMON ELECTRDOE
172a . . . COMB-TOOTH-LIKE PART
180 . . . CONDUCTOR
17
17
171
171
171
18

FIG. 8 PRIOR

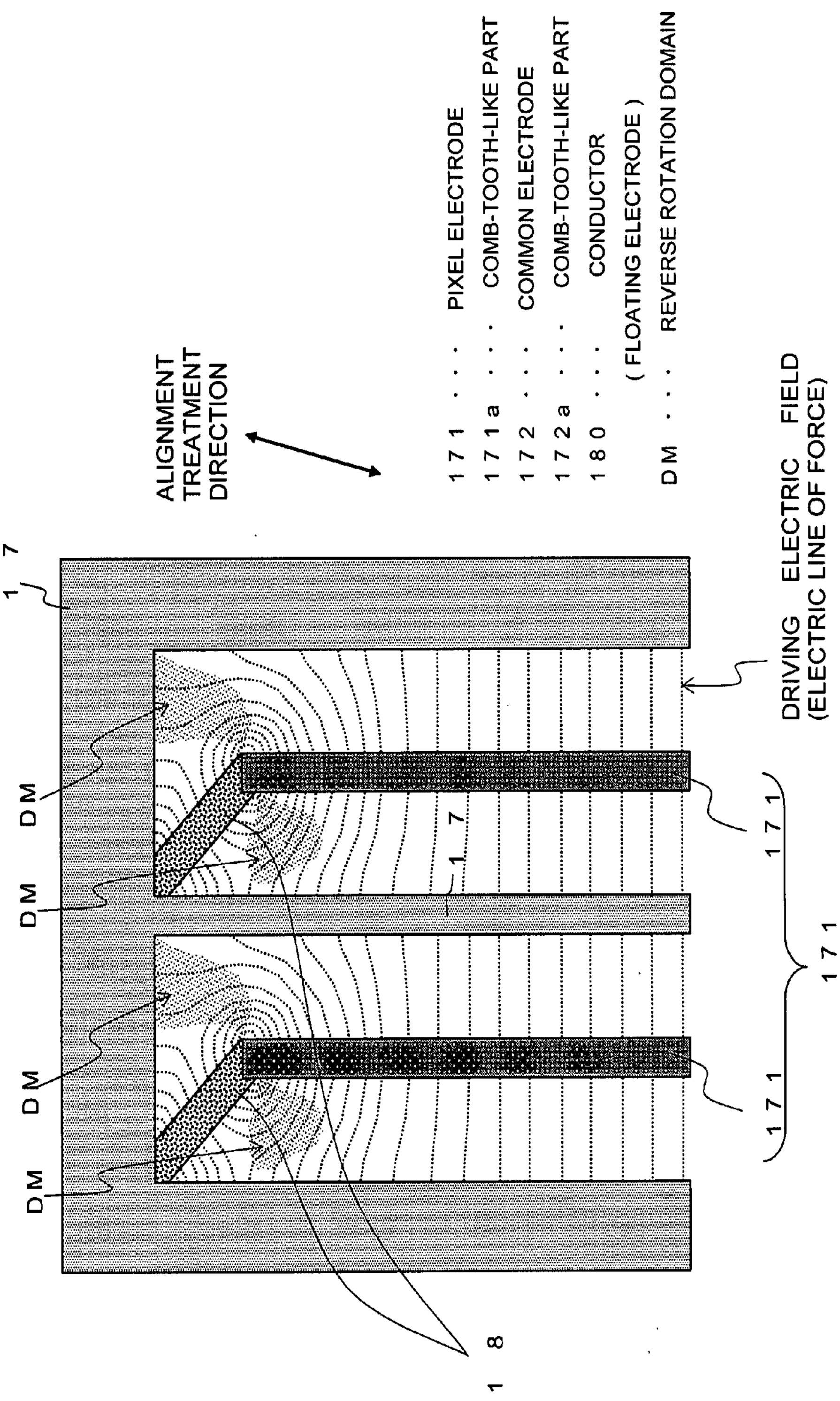

1 7
D M
D M
D M
D M
1 7
1 7 1
1 7 1
1 7 1
1 8
DRIVING ELECTRIC FIELD
(ELECTRIC LINE OF FORCE)
ALIGNMENT TREATMENT DIRECTION
1 7 1 . . . PIXEL ELECTRODE
1 7 1 a . . . COMB-TOOTH-LIKE PART
1 7 2 . . . COMMON ELECTRODE
1 7 2 a . . . COMB-TOOTH-LIKE PART
1 8 0 . . . CONDUCTOR
(FLOATING ELECTRODE)
D M . . . REVERSE ROTATION DOMAIN

FIG. 9

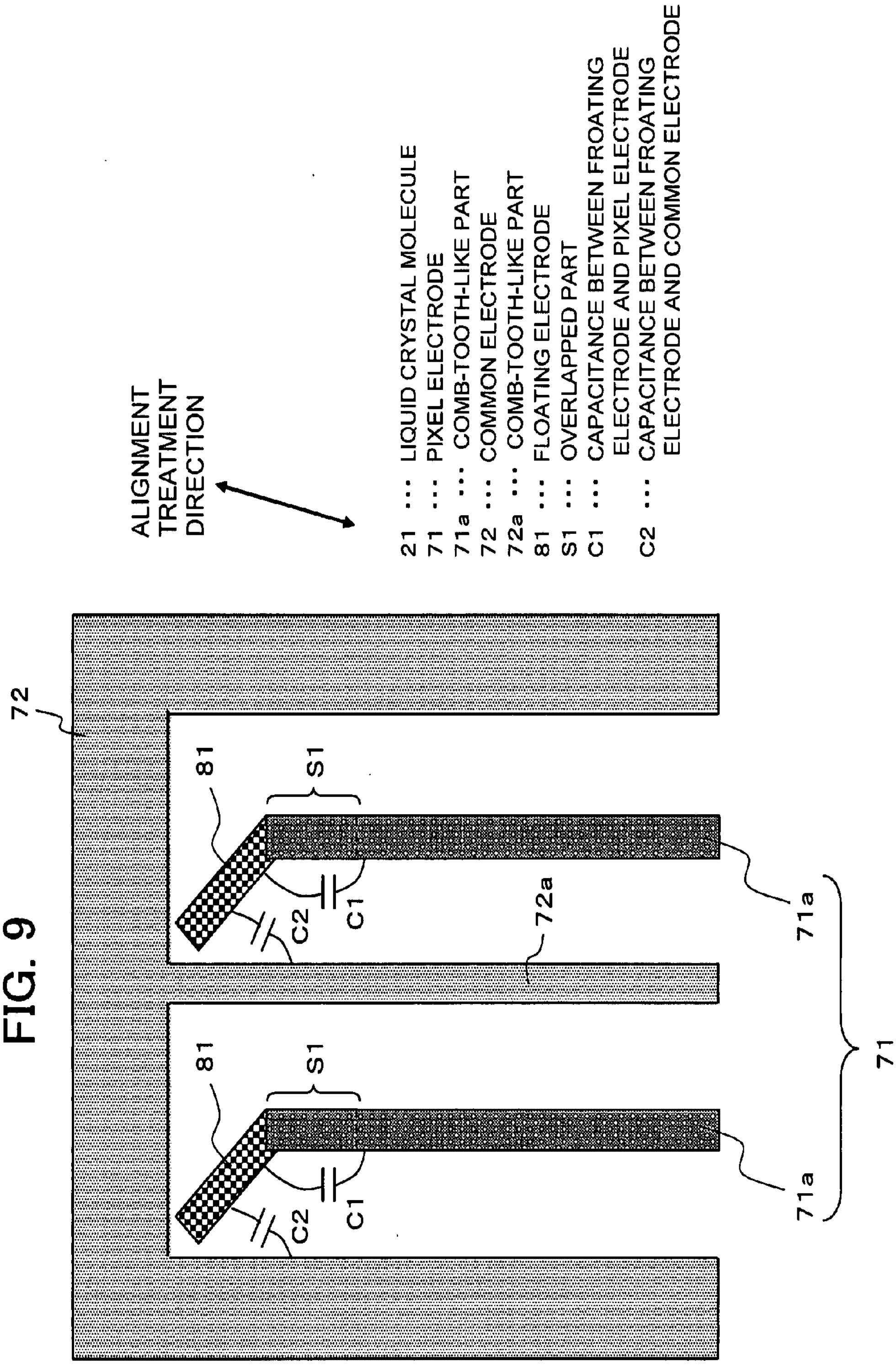

ALIGNMENT TREATMENT DIRECTION
21 ... LIQUID CRYSTAL MOLECULE
71 ... PIXEL ELECTRODE
71a ... COMB-TOOTH-LIKE PART
72 ... COMMON ELECTRODE
72a ... COMB-TOOTH-LIKE PART
81 ... FLOATING ELECTRODE
S1 ... OVERLAPPED PART
C1 ... CAPACITANCE BETWEEN FROATING ELECTRODE AND PIXEL ELECTRODE
C2 ... CAPACITANCE BETWEEN FROATING ELECTRODE AND COMMON ELECTRODE
72
81
S1
C1
C2
72a
71a
71

FIG. 10

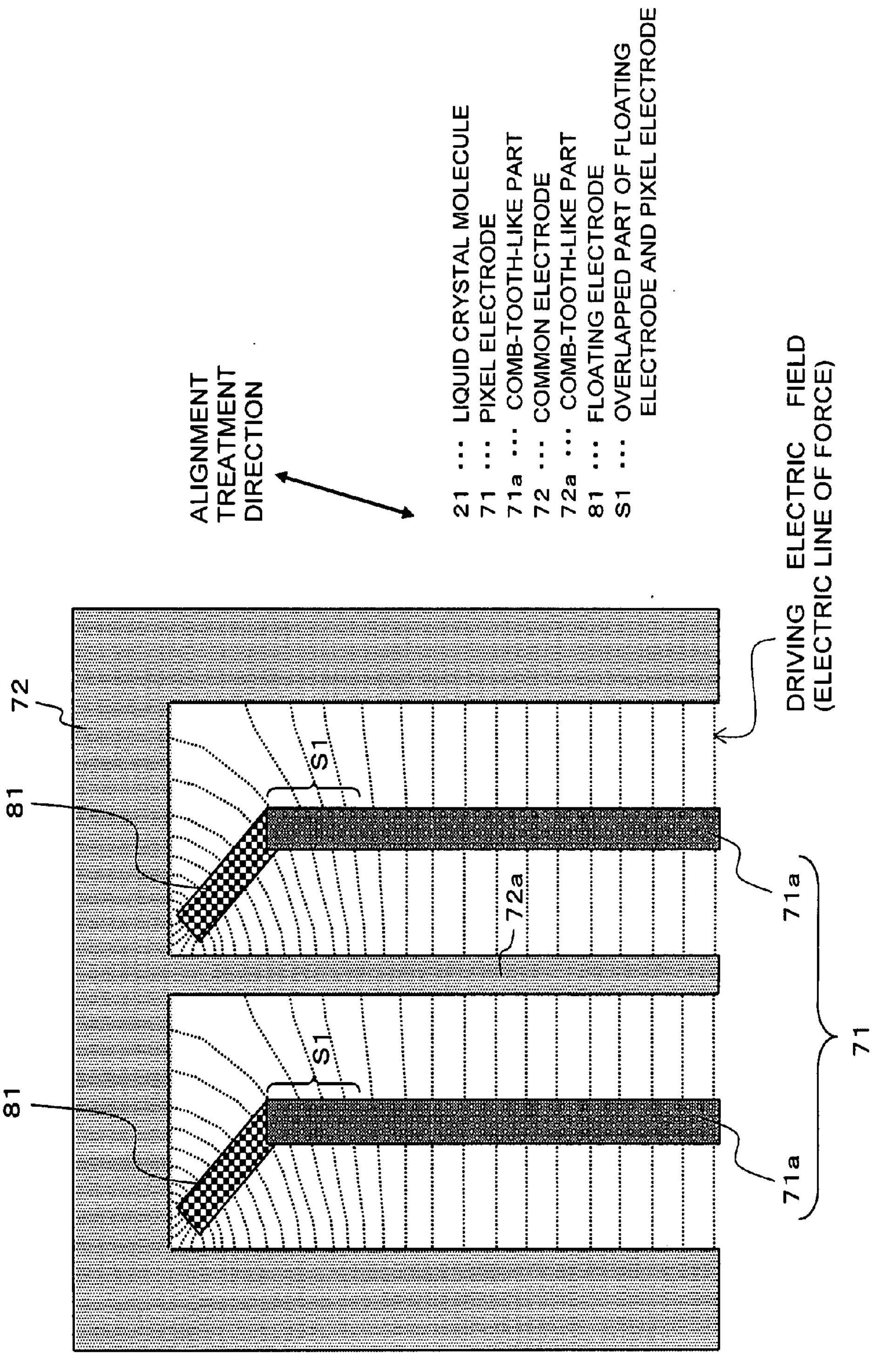
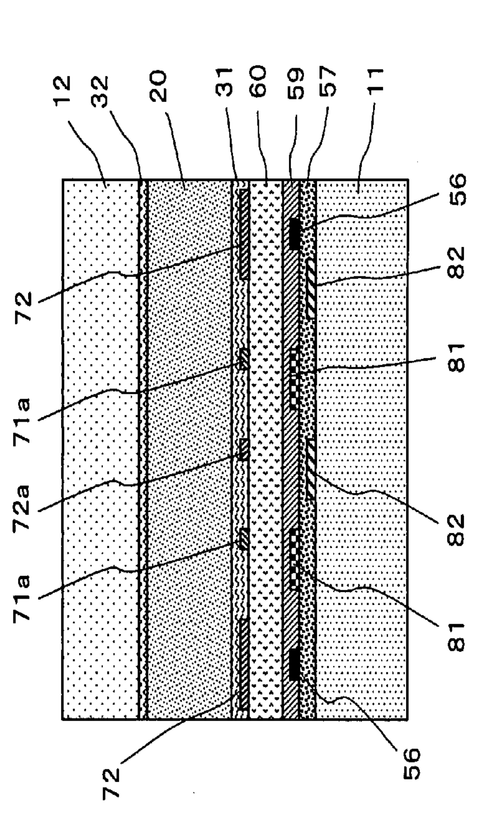
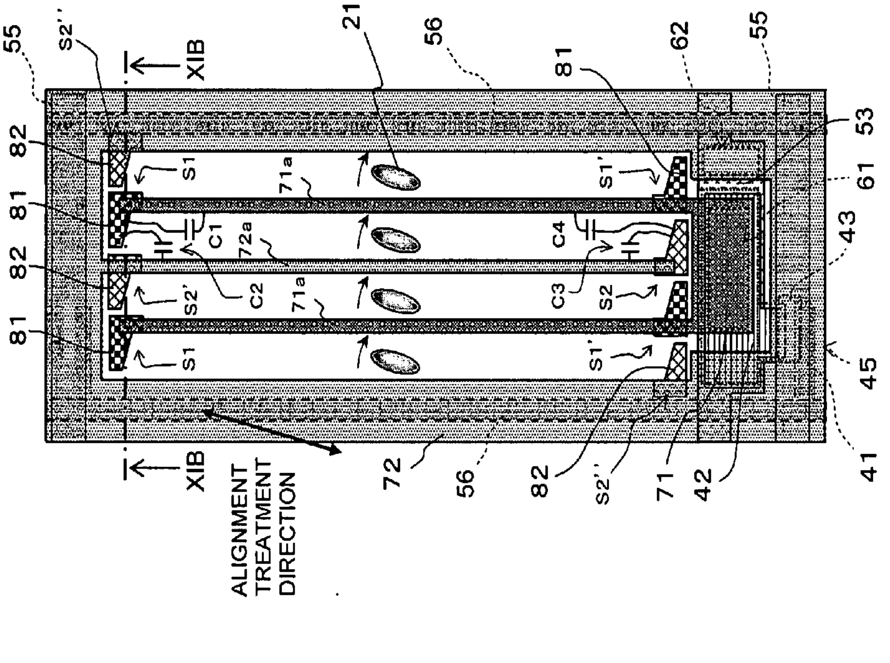

ALIGNMENT TREATMENT DIRECTION
21 … LIQUID CRYSTAL MOLECULE
71 … PIXEL ELECTRODE
71a … COMB-TOOTH-LIKE PART
72 … COMMON ELECTRODE
72a … COMB-TOOTH-LIKE PART
81 … FLOATING ELECTRODE
S1 … OVERLAPPED PART OF FLOATING ELECTRODE AND PIXEL ELECTRODE
72
81
81
S1
S1
72a
71a
71a
71
DRIVING ELECTRIC FIELD (ELECTRIC LINE OF FORCE)

FIG. 11B



11, 12 ··· GLASS PLATE
20 ··· LIQUID CRYSTAL
21 ··· LIQUID CRYSTAL MOLECULE
31, 32 ··· ALIGNMENT FILM
41 ··· DRAIN ELECTRODE
42 ··· SOURCE ELECTRODE
43 ··· SEMICONDUCTOR FILM
45 ··· THIN-FILM TRANSISTOR
53 ··· COMMON BUS LINE
55 ··· GATE BUS LINE
56 ··· DRAIN BUS LINE
57 ··· INTERLAYER INSULATING FILM
59 ··· PROTECTIVE INSULATING FILM
60 ··· ORGANIC INTERLAYER FILM
61, 62 ··· CONTACT HOLE
71 ··· PIXEL ELECTRODE
71a ··· COMB-TOOTH-LIKE PART
72 ··· COMMON ELECTRODE
72a ··· COMB-TOOTH-LIKE PART
81, 82 ··· FLOATING ELECTRODE
S1, S1' ··· OVERLAPPED PART OF FLOATING AND PIXEL ELECTRODES
S2, S2', S2'' ··· OVERLAPPED PART OF FLOATING AND COMMON ELECTRODES
C1, C4 ··· CAPACITANCE BETWEEN FLOATING AND PIXEL ELECTRODES
C2, C3 ··· CAPACITANCE BETWEEN FLOATING AND COMMON ELECTRODES

FIG. 11A



41 ··· DRAIN ELECTRODE
42 ··· SOURCE ELECTRODE
43 ··· SEMICONDUCTOR FILM
45 ··· THIN-FILM TRANSISTOR
53 ··· COMMON BUS LINE
55 ··· GATE BUS LINE
56 ··· DRAIN BUS LINE
81, 82 ··· FLOATING ELECTRODE

FIG. 12B

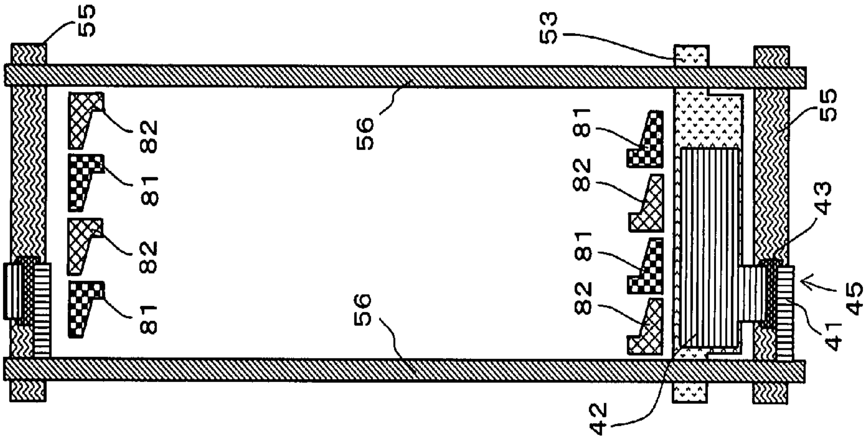
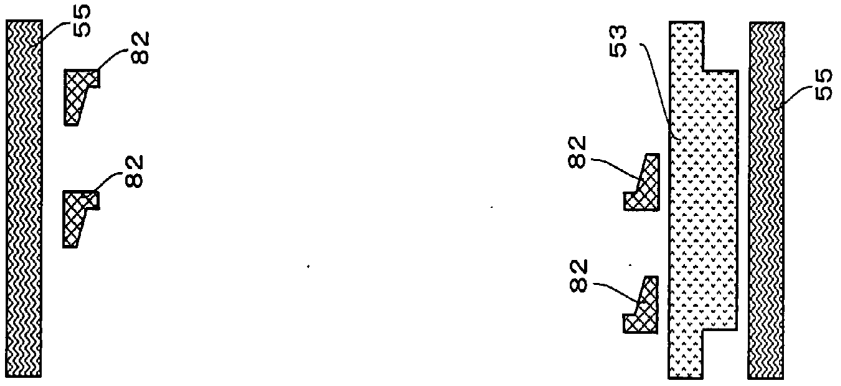


FIG. 12A



41 ··· DRAIN ELECTRODE
42 ··· SOURCE ELECTRODE
43 ··· SEMICONDUCTOR FILM
45 ··· THIN-FILM TRANSISTOR
53 ··· COMMON BUS LINE
55 ··· GATE BUS LINE
56 ··· DRAIN BUS LINE
61, 62 ··· CONTACT HOLE
71 ··· PIXEL ELECTRODE
71a ··· COMB-TOOTH-LIKE PART
72 ··· COMMON ELECTRODE
72a ··· COMB-TOOTH-LIKE PART
81, 82 ··· FLOATING ELECTRODE

FIG. 13B

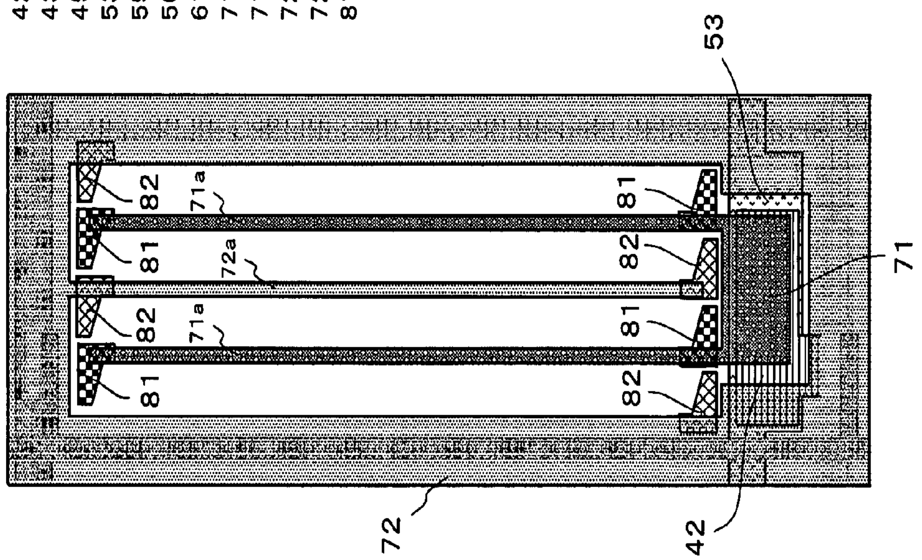


FIG. 13A

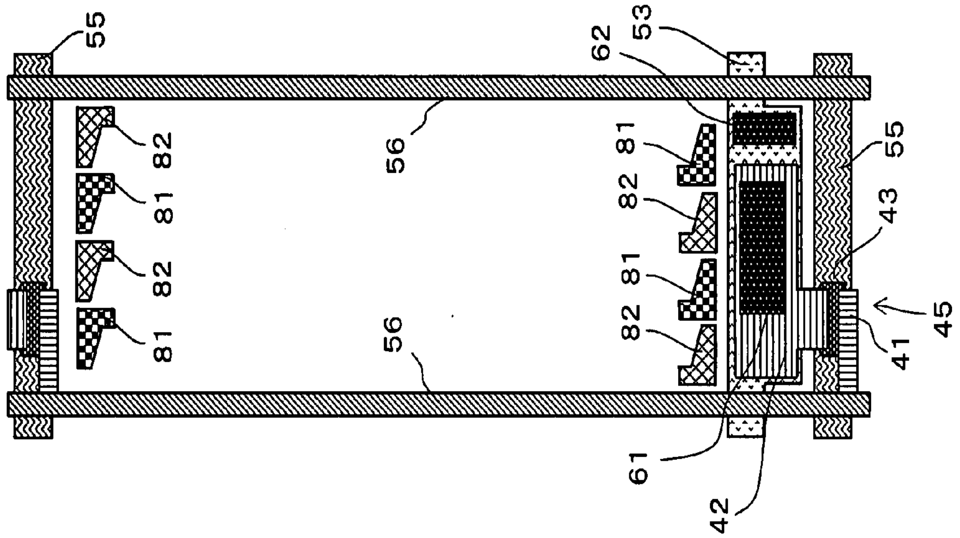


FIG. 14

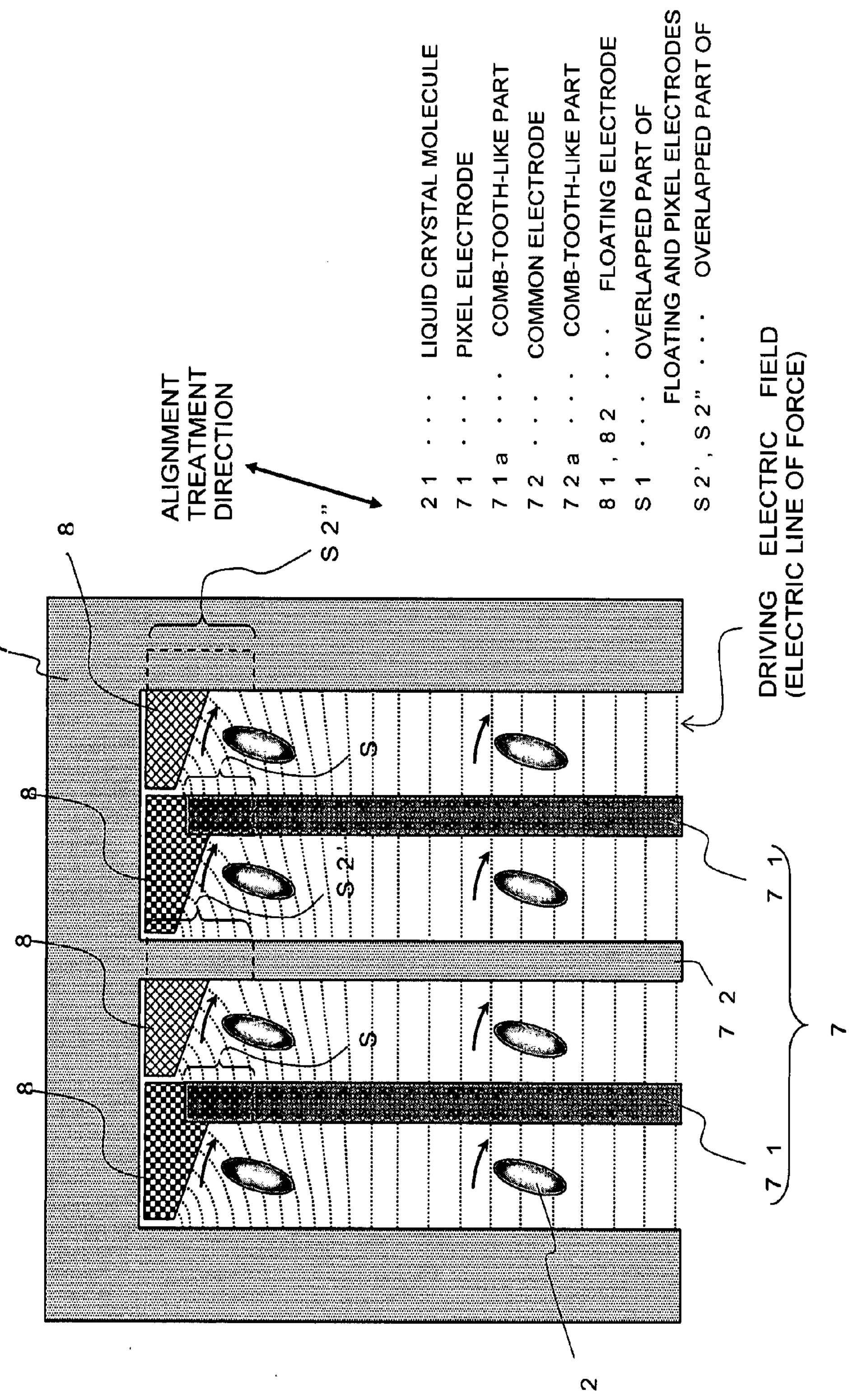

ALIGNMENT TREATMENT DIRECTION
21 . . . LIQUID CRYSTAL MOLECULE
71 . . . PIXEL ELECTRODE
71a . . . COMB-TOOTH-LIKE PART
72 . . . COMMON ELECTRODE
72a . . . COMB-TOOTH-LIKE PART
81, 82 . . . FLOATING ELECTRODE
S1 . . . OVERLAPPED PART OF FLOATING AND PIXEL ELECTRODES
S2', S2" . . . OVERLAPPED PART OF
DRIVING ELECTRIC FIELD (ELECTRIC LINE OF FORCE)
S2"
S
S2'
8
7
71
72
2

FIG. 15

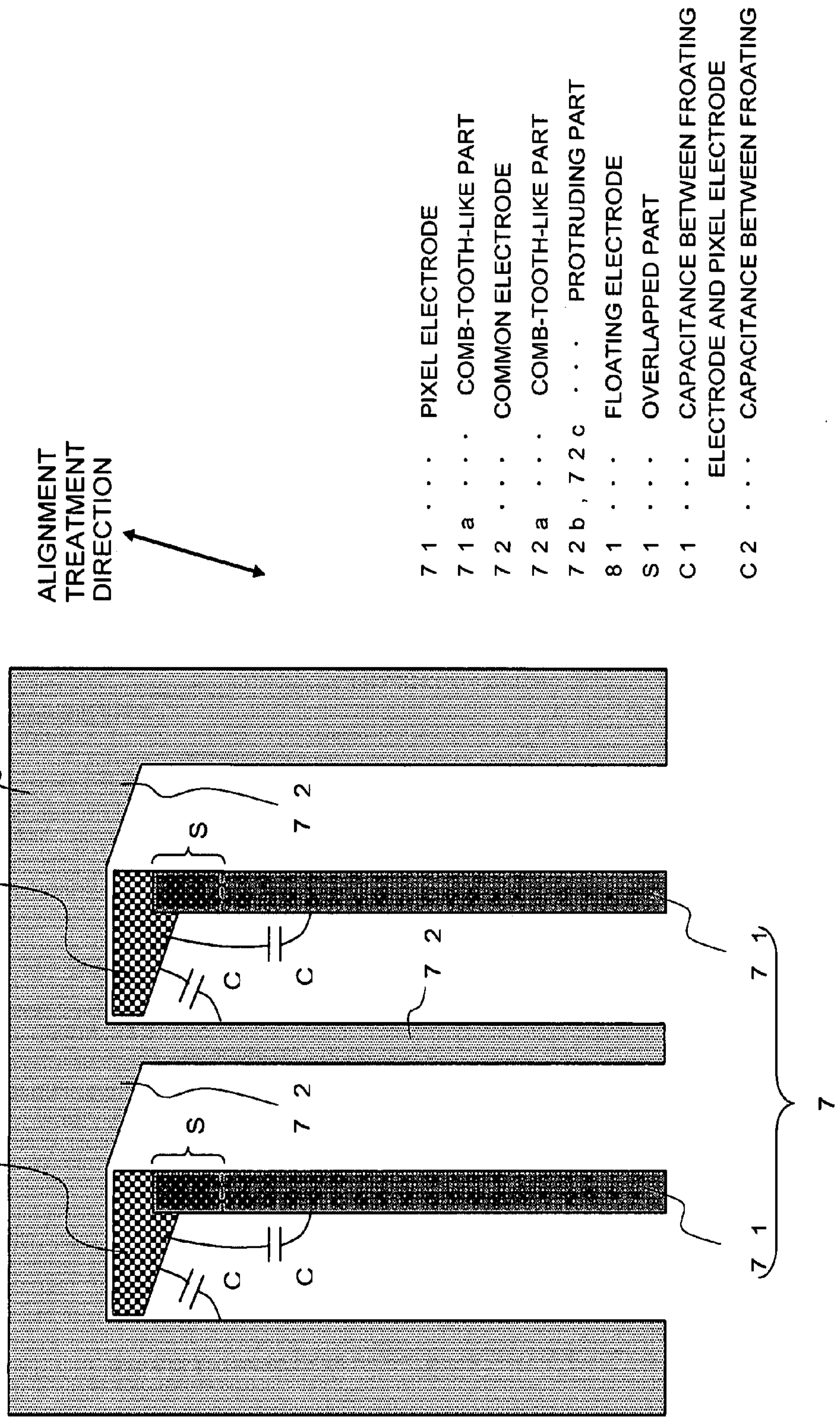

ALIGNMENT TREATMENT DIRECTION
71 . . . PIXEL ELECTRODE
71a . . . COMB-TOOTH-LIKE PART
72 . . . COMMON ELECTRODE
72a . . . COMB-TOOTH-LIKE PART
72b, 72c . . . PROTRUDING PART
81 . . . FLOATING ELECTRODE
S1 . . . OVERLAPPED PART
C1 . . . CAPACITANCE BETWEEN FROATING ELECTRODE AND PIXEL ELECTRODE
C2 . . . CAPACITANCE BETWEEN FROATING
7
72
S
8
C
71

FIG. 16A

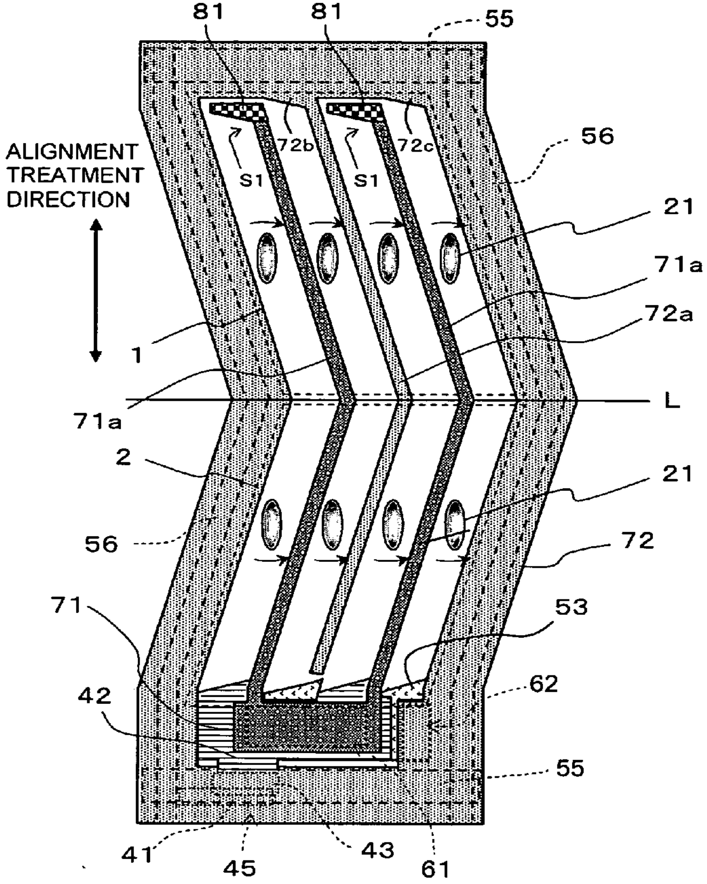


FIG. 16C

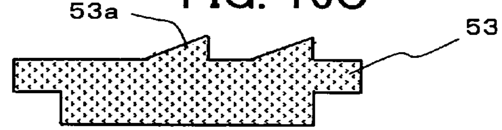
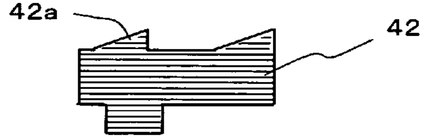


FIG. 16B



1, 2 ··· SUBREGION
21 ··· LIQUID CRYSTAL MOLECULE
41 ··· DRAIN ELECTRODE
42 ··· SOURCE ELECTRODE
42a ··· PROTRUDING PART
43 ··· SEMICONDUCTOR FILM
45 ··· THIN-FILM TRANSISTOR
53 ··· COMMON BUS LINE
53a ··· PROTRUDING PART
55 ··· GATE BUS LINE
56 ··· DRAIN BUS LINE
61, 62 ··· CONTACT HOLE
71 ··· PIXEL ELECTRODE
71a ··· COMB-TOOTH-LIKE PART
72 ··· COMMON ELECTRODE
72a ··· COMB-TOOTH-LIKE PART
72b, 72c ··· PROTRUDING PART
81 ··· FLOATING ELECTRODE
S1 ··· OVERLAPPED PART OF FLOATING AND PIXEL ELECTRODES

LATERAL ELECTRIC FIELD TYPE LIQUID-CRYSTAL DISPLAY DEVICE

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a Liquid-crystal Display (LCD) device and more particularly, to a LCD device of the lateral electric field (In-Plane Switching, IPS) type.

[0003] 2. Description of the Related Art

[0004] Generally, the LCD device has the feature of thin, lightweight, and low power consumption. In particular, the active-matrix addressing LCD (AM LCD) device that drives the respective pixels arranged in a matrix array with the active elements has ever been recognized as a high image quality flat panel display device. Especially, the AM LCD device using thin-film transistors (TFTs) (i.e., TFT-LCD) as the active elements has been extensively diffused.

[0005] Most of active-matrix addressing LCD devices, which utilize the electrooptic effects of the TN (Twisted Nematic) type liquid crystal sandwiched by two substrates, display images by applying an electric field approximately vertical to the surfaces of the substrates across the liquid crystal to thereby cause displacement of the liquid crystal molecules. These LCD devices are termed the "vertical electric field" type. On the other hand, some LCD devices display images by applying an electric field approximately parallel to the surfaces of the substrates to thereby cause displacement of the liquid crystal molecules in the planes parallel to the surfaces of the substrates. These LCD devices have been known also, which are termed the "lateral electric field" type. Various improvements have ever been made for the lateral electric field type LCD devices also. Some of the improvements will be exemplified below.

[0006] A structure using comb-tooth-like electrodes mated with each other in the lateral electric field type LCD device is disclosed in the U.S. Pat. No. 3,807,831 issued in 1974 (refer to claim 1, FIGS. 1 to 4 and FIG. 11).

[0007] A technique using comb-tooth-like electrodes mated with each other similar to those in the U.S. Pat. No. 3,807,831 in the active-matrix addressing LCD device utilizing the electrooptic effects of the TN type liquid crystal is disclosed in the Japanese Unexamined Patent Publication No. 56-091277 published in 1981 (refer to claim 2, FIG. 7 and FIGS. 9 to 13). This technique reduces the parasitic capacitance between the common electrode and the drain bus lines, or that between the common electrode and the gate lines.

[0008] A technique that realizes a lateral electric field type LCD device without the comb-tooth-like electrodes in the active-matrix addressing LCD device using TPTs is disclosed in the Japanese Unexamined Patent Publication No. 7-036058 published in 1995 (refer to claims 1 and 5, FIGS. 1 to 23). With this technique, the common electrode and the image signal electrodes or the common electrode and the liquid-crystal driving electrodes are formed on different layers and at the same time, the common electrode or the liquid-crystal driving electrodes is/are formed to be ring-, cross-, T-, ?-, H-, or ladder-shaped.

[0009] A structure that the pixel electrode and the common electrode for generating the liquid-crystal driving lateral electric field (both of which are comb-tooth-shaped) are disposed above (i.e., at closer positions to the liquid crystal layer) the bus lines (i.e., data lines) that supply signals to the active elements for driving the respective pixels, where an insulating layer intervenes between the pixel electrodes and the common electrode, is disclosed In the Japanese Unexamined Patent Publication No. 2002-323706 published in 2002 (refer to claim 1, first embodiment. FIGS. 1 to 2). It is said that with this structure, since the electric field from the bus lines can be shielded by forming the common electrode to cover the bus lines, defective display caused by vertical crosstalk is prevented. Moreover, it is said that the aperture ratio is raised by forming the common electrode with a transparent conductive material.

[0010] FIGS. **1** and **2** are drawing figures explaining an example of the structure of a prior-art popular lateral electric field type active-matrix addressing LCD device. FIG. **1** is a plan view of the device, FIG. **2**A is a cross-sectional view along the line IIA-IIA in FIG. **1**, and FIG. **2**B is a cross-sectional view along the line IIB-IIB in FIG. **1**. Moreover, FIGS. **3**A and **3**B and FIGS. **4**A and **4**B are partial plan views showing the fabrication steps of the said LCD device. All of these figures show the structure of one pixel region.

[0011] With the prior-art LCD device, as shown in FIGS. **1** and **3**B, rectangular regions are formed by gate bus lines **155** extending along the horizontal direction of FIGS. **1** and **3**B and drain bus lines **156** extending along the vertical direction thereof. Pixel regions are formed in the respective rectangular regions. Pixels are arranged in a matrix array as a whole. Common bus lines **153** are formed to extend along the horizontal direction of FIGS. **1** and **3**B, similar to the gate bus lines **155**. At the respective intersections of the gate and drain bus lines **155** and **156**. TFTs **145** are formed corresponding to the respective pixels. The drain electrode **141**, the source electrode **142**, and the semiconductor film **143** of each TFT **145** are formed to have the patterns (shapes) shown in FIG. **3**B, respectively.

[0012] The pixel electrode **171** and the common electrode **172**, which generate a liquid-crystal driving electric field, comprise comb-tooth-like parts (i.e., thin belt-shaped parts protruding into the pixel region) **171***a* and **172***a* mated or engaged with each other, respectively. Here, the count of the comb-tooth-like parts **171***a* of the pixel electrode **171** is two and the count of the comb-tooth-like parts **172***a* of the common electrode **172** is one. As shown in FIG. **2**A, the pixel electrode **171** is electrically connected to the corresponding source electrode **142** of the TFT **145** by way of the corresponding contact hole **161** that penetrates through an organic interlayer film **160** and a protective insulating film **159**. The common electrode **172** is electrically connected to the corresponding common bus line **153** by way of the corresponding contact hole **162** that penetrates through the organic interlayer film **160**, the protective insulating film **159**, and an interlayer insulating film **157**. Part of the source electrode **142** of the TFT **145** is overlapped with the corresponding common bus line **153**, thereby forming a storage capacitor for the said pixel region by the said overlapped part.

[0013] The cross-sectional structure of the said prior-art LCD device is shown in FIGS. **2**A and **2**B, where this device is configured by coupling and unifying an active-matrix substrate and an opposite substrate to sandwich a liquid crystal between them.

[0014] The active-matrix substrate comprises a transparent glass plate **111**; and the common bus lines **153**, the gate bus lines **155**, the drain bus lines **156**, the TFTs **145**, the pixel electrodes **171**, and the common electrode **172**, all of which are formed on or over the inner surface of the glass plate **111**. The common bus lines **153** and the gate bus lines **155**, which are directly formed on the inner surface of the glass plate **111**, are covered with the interlayer insulating film **157**. The drain electrodes **141**, the source electrodes **142**, and the semiconductor films **143** of the TFTs **145**, and the drain bus lines **156** are formed on the interlayer insulating film **157**. Thus, the common bus lines **153** and the gate bus lines **155** are electrically insulated from the drain electrodes **141**, the source electrodes **142**, the semiconductor films **143**, and the drain bus lines **156** by the interlayer insulating film **157**. These structures formed on the glass plate **111** are covered with the protective insulating film **159** except for the regions where the contact holes **161** and **162** are formed. The level differences caused by the contact holes **161** and **162** are planarized by the organic interlayer film **160** formed on the protective insulating film **159**. The pixel electrodes **171** and the common electrode **172** are formed on the organic interlayer film **160**. As explained above, the pixel electrode **171** is electrically connected to the corresponding source electrode **142** by way of the corresponding contact hole **161**, and the common electrode **172** is electrically connected to the corresponding common bus line **153** by way of the corresponding contact hole **162**. In addition, the cross-sectional views of FIGS. **2**A and **2**B are schematically drawn and thus, they do not reproduce the actual level differences faithfully.

[0015] The surface of the active matrix substrate having the above-described structure, on which the pixel electrodes **171** and the common electrode **172** are formed, is covered with an alignment film **131** formed by an organic polymer film. The surface of the alignment film **131** has been subjected to an alignment treatment for directing the initial orientation direction of the liquid crystal molecules **121** to a desired direction (see the arrow in FIG. **1**).

[0016] On the other hand, the opposite substrate (i.e., the color filter substrate) comprises a transparent glass plate **112**; and a color filter (not shown) including the three primary colors of red (R), green (G) and blue (B) formed corresponding to the respective pixel regions, and a light-shielding black matrix (not shown) formed in the regions other than those corresponding to the respective pixel regions. The color filter and the black matrix, which are formed on the inner surface of the glass plate **112**, are covered with an acrylic-based overcoat film (not shown). On the inner surface of the overcoat film, columnar spacers (not shown) are formed to control the interval between the active-matrix substrate and the opposite substrate. The inner surface of the overcoat film is covered with an alignment film **132** formed by an organic polymer film. The surface of the alignment film **132** has been subjected to an alignment treatment for directing the initial orientation direction of the liquid crystal molecules **121** to a desired direction (see the arrow in FIG. **1**).

[0017] The active-matrix substrate and the opposite substrate each having the above-described structure are superposed on each other at a predetermined interval in such a way that their surfaces on which the alignment films **131** and **132** are respectively formed are directed inward and opposed to each other. A liquid crystal **120** is introduced into the gap between these two substrates. The peripheries of the substrates are sealed by a sealing member (not shown) to confine the liquid crystal **120** therein. A pair of polarizer plates (not shown) is arranged on the outer surfaces of the said substrates, respectively.

[0018] The surfaces of the alignment films **131** and **132** have been uniformly alignment-treated in such a way that the liquid crystal molecules **121** are aligned in parallel along the desired direction when no electric field is applied, as described above. The alignment direction by the alignment treatments is a direction inclined clockwise by 15° with respect to the direction along which the comb-tooth-like parts **171***a* and **172***a* of the pixel and common electrodes **171** and **172** are extended (i.e., the vertical direction in FIG. **1**).

[0019] The transmission axes of the pair of polarizer plates are crossed at right angles. The transmission axis of one of the pair of polarizer plates is in accordance with the initial alignment direction of the liquid crystal molecules **121** determined by the uniform alignment treatment.

[0020] Next, the fabrication process steps of the prior-art LCD device shown in FIGS. **1**, **2**A, and **2**B will be explained below with reference to FIGS. **3**A and **3**B and FIGS. **4**A and **4**B.

[0021] The active-matrix substrate is fabricated in the following way. First, a chromium (Cr) film is formed on one of the surfaces of the glass plate **111** and patterned, thereby forming the common bus lines **153** and the gate bus lines **155** having the shapes of FIG. **3**A. Thereafter, the interlayer insulating film **157**, which is formed by a silicon nitride (SiN_x) film, is formed to cover the common bus lines **153** and the gate bus lines **155** over the whole surface of the glass plate **111**. Subsequently, the semiconductor films **143** (which are usually formed by an amorphous silicon (a-Si) film) are formed to have island-shaped patterns on the interlayer insulating film **157** in such a way as to be overlapped with the corresponding gate bus lines **155** by way of the interlayer insulating film **157**. A Cr film is then formed on the interlayer insulating film **157** and patterned, thereby forming the drain bus lines **156**, the drain electrodes **141** and the source electrodes **142** (see FIG. **3**B). Thereafter, the protective insulating film **159** made of SiN_x and the organic interlayer film **160** made of photosensitive acrylic resin are successively stacked on the interlayer insulating film **157** in this order to cover these structures. Following this, the rectangular contact holes **161** penetrating through the protective insulating film **159** and the organic interlayer film **160** and the rectangular contact holes **162** penetrating through the interlayer insulating film **157**, the protective insulating film **159**, and the organic interlayer film **160** are formed (see FIG. **4**A). An ITO (Indium Tin Oxide) film, which is a transparent conductive material, is formed on the organic interlayer film **160** and patterned, thereby forming the pixel electrodes **171** and the common electrode **172** on the organic interlayer film **160**. The pixel electrodes **171** are in contact with the corresponding source electrodes **142** by way of the corresponding contact holes **161**. The common electrode **172** is in contact with the common bus lines **153** by way of the corresponding contact holes **162** (see FIGS. **4**B and **2**A). In this way, the active-matrix substrate is fabricated.

[**0022**] The opposite substrate (the color filer substrate) is fabricated in the following way. First, the color filter (not shown) and the light-shielding black matrix (not shown) are formed on one of the surfaces of the glass plate **112** and thereafter, the overcoat film (not shown) is formed to cover the color filter and the black matrix over the whole surface of the glass plate **112**. Then, the columnar spacers (not shown) are formed on the overcoat film. In this way, the opposite substrate is fabricated.

[**0023**] The alignment films **131** and **132**, which are made of polyimide, are formed on the surface of the active-matrix substrate and the surface of the opposite substrate fabricated as described above, respectively. Next, the surfaces of the alignment films **131** and **132** are uniformly alignment-treated. These two substrates are then superposed to have a constant, interval (e.g., approximately 4.5 μm), and the peripheries of the coupled substrates are sealed by the sealing member except for an injection hole for the liquid crystal. Next, in a vacuum chamber, a predetermined nematic liquid crystal (e.g., a nematic liquid crystal whose refractive index anisotropy is 0.067) is injected into the gap between the substrates through the injection hole and then, the injection hole is closed. After the substrates are coupled and unified in this way, the polarizer plates (not shown) are respectively adhered on the outer surfaces of the substrates. As a result, the prior-art LCD device having the structure shown in FIGS. **1**, **2**A and **2**B is completed.

[**0024**] With the prior-art lateral electric field type LCD device described above, it is known that the liquid crystal molecules **121** are rotated to the direction opposite to the ordinary rotation direction in some regions (which are termed “reverse rotation domains”) when the liquid-crystal driving electric field is applied. If such the reverse rotation domains are generated, there is the possibility that some problems, such as the display uniformity degradation in the overall LCD device and the image burn-in due to long time operation, will arise from the viewpoint of image quality and reliability. Therefore, the reverse rotation domains need to be prevented from occurring.

[**0025**] A structure for preventing the reverse rotation domain (i.e., the reverse-rotation domain preventing structure) is disclosed in the above-described Publication No. 2002-323706. However, in addition to this structure, other structures are disclosed in the Japanese Unexamined Patent Publication No. 10-26767 published in 1998 and the Japanese Unexamined Patent Publication No. 2000-330123 published in 2000.

[**0026**] The reverse-rotation domain preventing structure disclosed in the Japanese Unexamined Patent Publication No. 2002-323706 is realized by patterning the pixel auxiliary electrodes and the common auxiliary electrodes to have slant edges in their insides, as described in the paragraphs 0247 to 0256 and FIG. **19**. In other words, the edges of the pixel auxiliary electrodes and the common auxiliary electrodes on the central sides of the respective pixel regions are protruded to be sawtooth-shaped, thereby forming respectively the inclined edges with respect to the drain bus lines on the pixel auxiliary electrodes and the common auxiliary electrodes.

[**0027**] The reverse-rotation domain preventing structure disclosed in the Japanese Unexamined Patent Publication No. 10-26767 is shown in its claims 1 to 8 and FIGS. 1 to 6, as follows. Specifically, the initial alignment direction of the liquid crystal molecules and the direction of the liquid-crystal driving electric field are respectively maintained in predetermined ranges within the entire sub-pixel region or regions sandwiched by the parallel electrode pair in each pixel, with respect to the direction perpendicular to the running direction of the parallel electrode pair.

[**0028**] The reverse-rotation domain preventing structure disclosed in the Japanese Unexamined Patent Publication No. 2000-330123 is shown in its claims 1 to 3, FIGS. 1 to 5, and the first and second embodiments, as follows. Specifically, a bent part or parts, which is/are bent toward the opposite direction to the alignment direction of the liquid crystal molecules with respect to the image signal lines, is/are formed at the end(s) of at least one of the pixel electrode and the opposite electrode. Moreover, it is said that the bent part(s) is/are preferably formed at the end(s) of the comb-tooth-like pixel electrode or the comb-tooth-like opposite electrode or both.

[**0029**] FIG. **5** is a diagram schematically showing the generation principle of the reverse rotation domain in the prior-art LCD device shown in FIGS. **1** to **4**B. To facilitate the explanation, only the pixel electrode **171**, the common electrode **172** and the liquid crystal molecules **121** are shown in FIG. **5**. In FIG. **5**, the liquid-crystal driving electric field (its electric lines of force), which is generated by the comb-tooth-like parts **171***a* of the pixel electrode **171** and the comb-tooth-like part **172***a* of the common electrode **172**, is schematically illustrated.

[**0030**] The rotation direction of the liquid crystal molecules **121** (the rotation of the molecules **121** is caused in planes approximately parallel to the active-matrix substrate and the opposite substrate) is defined by the relationship between the initial alignment direction of the molecules **121** and the direction of the liquid-crystal driving electric field. Therefore, the rotation direction of the molecules **121** is “clockwise” in almost all the said pixel region. However, in the vicinities of the comb-tooth-like parts **171***a* of the pixel electrode **171**, the liquid-crystal driving electric field is radial, as shown in FIG. **5**. Thus, the molecules **121** are rotated “counterclockwise” in the shadowed regions in said figure. This means that the shadowed regions are the reverse rotation domains DM where the molecules **121** are rotated “counterclockwise”.

[**0031**] FIG. **6** is a diagram schematically showing the principle of restraining the generation of the reverse rotation domain DM when the reverse-rotation domain preventing structure disclosed in the above-described Publication No. 2000-330123 is adopted. The reverse-rotation domain preventing structure in FIG. **6** is that bent parts **171***b* are formed at the respective ends of the comb-tooth-like parts **171***a* of the pixel electrode **171**. The bent parts **171***b* are bent toward the opposite direction to the initial alignment direction (i.e., the alignment treatment direction) of the liquid crystal molecules with respect to the running direction of the comb-tooth-like parts **171***a*. Due to the existence of the bent parts **171***b*, the direction of the liquid-crystal driving electric field in the vicinities of the ends of the comb-tooth-like parts **171***a* is changed to the state shown by broken lines in FIG.

6. This means that the ranges where the liquid-crystal driving electric field is radial are reduced. As a result, the generation of the reverse rotation domain DM is restrained.

[0032] In the above-described Publication No. 2000-330123. In addition to the structure that the bent parts **171***b* are formed in the vicinities of the ends of the comb-tooth-like parts **171***a* shown in FIG. **6**, another reverse-rotation domain preventing structure shown in FIG. **7** is disclosed (see claims 8 to 10, FIGS. 6 to 9 and the third to fifth embodiments). The structure of FIG. **7** is that thin belt-shaped conductors **180** are provided in the vicinities of the ends of the comb-tooth-like parts **171***a* of the pixel electrode **171** in such a way that an insulating film (not shown) intervenes between the ends of the parts **171***a* and the conductors **180**. The conductors **180** comprise slant sides inclined with respect to the running direction of the comb-tooth-like parts **171***a* toward the opposite direction to the initial alignment direction of the liquid crystal molecules. Since the conductors **180** are electrically isolated from not only the pixel electrodes **171** and the common electrode **172** but also the other electrodes, they may be termed "floating electrodes" also.

[0033] Furthermore, the Japanese Unexamined Patent Publication No. 10-307295 published in 1998 discloses a technique that the electrodes for generating lateral electric field are bent to intentionally make the driving (rotating) direction of the liquid crystal molecules different in the respective regions with the said bent parts of the electrodes, thereby reducing the display coloring in the slant views (see claim 1, 3 and 5, and FIGS. 1, 2, 4 and 6).

[0034] For example, the following structure is taken. Specifically, the initial alignment direction of the liquid crystal molecules in the first subregion is equalized to that in the second subregion. When a voltage is applied, the liquid crystal molecules in the first and second subregions are rotated in opposite directions to each other while keeping the alignment directions of the liquid crystal molecules symmetrically in the first and second subregions (see claim 3). With this structure, preferably, the lateral electric field for driving the liquid crystal molecules is generated by the parallel electrode pair, and the electrodes constituting the parallel electrode pairs are bent into a V shape (see claim 5).

[0035] According to the study result by the inventors of the present invention, with the reverse-rotation domain preventing structure shown in FIG. **7** using the floating electrodes **180**, it has been found that the generation of the reverse rotation domain is not fully restrained. The reason is as follows.

[0036] With the reverse-rotation domain preventing structure of FIG. **7**, the floating electrodes **180**, which are made of electrically isolated conductors by an insulating film (not shown), are provided in the vicinities of the ends of the comb-tooth-like parts **171***a* of the pixel electrode **171**. Therefore, when a voltage is applied between the pixel electrode **171** and the common electrode **172** to generate a liquid-crystal driving electric field, the electric potential of each floating electrode **180** is determined at a predetermined value by a capacitance formed by the pixel electrode **170**, the floating electrode **180**, and the insulating film intervening between the electrodes **170** and **180**, and another capacitance formed by the common electrode **172**, the floating electrode **180**, and the insulating film intervening between the electrodes **172** and **180**. The qualitative appearance of the resultant liquid-crystal driving electric field (its electric lines of force) is shown by broken lines in FIG. **8**.

[0037] As seen from the relationship between the direction of the electric lines and the initial alignment direction of the liquid crystal molecules shown in FIG. **8**, a torque that rotates the liquid crystal molecules to the opposite direction (i.e., counterclockwise) to the normal rotation direction is applied to the liquid crystal molecules in the shadowed regions in FIG. **8**. This means that even if the reverse-rotation domain preventing structure of FIG. **7** is adopted, the generation of the reverse rotation domain DM is not restrained in the vicinities of the ends of the comb-tooth-like parts **171***a* of the pixel electrode **171**.

SUMMARY OF THE INVENTION

[0038] The present invention was created in consideration of the above-described point and Its object is to provide a lateral electric field type LCD device that makes it sure to prevent the generation of the reverse rotation domain when the reverse-rotation domain preventing structure using the floating electrodes is adopted.

[0039] Another object of the present invention is to provide a lateral electric field type LCD device having improved image quality and improved reliability.

[0040] The above objects together with others not specifically mentioned will become clear to those skilled in the art from the following description.

[0041] A lateral electric field type LCD device according to the present invention comprises:

[0042] a first substrate and a second substrate arranged to be opposite to each other at an approximately constant interval:

[0043] a liquid crystal arranged between the first and second substrates; and

[0044] a first liquid-crystal driving electrode and a second liquid-crystal driving electrode, which are formed on one of the first and second substrates;

[0045] wherein an alignment direction of molecules of the liquid crystal is rotated in planes approximately parallel to the first and second substrates to display images by applying a liquid-crystal driving electric field approximately parallel to the first and second substrates to the liquid crystal using the first and second liquid-crystal driving electrodes;

[0046] the first and second liquid-crystal driving electrodes comprise comb-tooth-like parts extending approximately parallel to each other and being meshed or engaged with each other, respectively, in a region where images are displayed by applying the liquid-crystal driving electric field to the liquid crystal;

[0047] an electrically isolated first floating electrode is provided in a vicinity of a top end of the comb-tooth-like part of the first liquid-crystal driving electrode, where the first floating electrode comprises an overlapped part which is overlapped with the top end by way of an insulating film; and

[0048] a capacitance intervening between the first floating electrode and the first liquid-crystal driving electrode is greater than a capacitance intervening between the first floating electrode and the second liquid-crystal driving electrode.

[0049] With the lateral electric field type LCD device according to the present invention, as described above, the electrically isolated first floating electrode is provided in the vicinity of the top end of the comb-tooth-like part of the first liquid-crystal driving electrode (e.g., the pixel electrode), and the first floating electrode comprises the overlapped part which is overlapped with the top end by way of the insulating film. Moreover, the capacitance intervening between the first floating electrode and the first liquid-crystal driving electrode is greater than the capacitance intervening between the first floating electrode and the second liquid-crystal driving electrode. Therefore, when a voltage is applied between the first and second liquid-crystal driving electrodes to generate the liquid-crystal driving electric field and exert the electric field on the liquid crystal, the electric potential of the first floating electrode is closer to the electric potential of the first liquid-crystal driving electrode than the electric potential of the second liquid-crystal driving electrode. This means that the electric lines of force in the vicinity of the first floating electrode are similar to the electric lines of force obtained in the case where the prior-art reverse-rotation domain preventing structure shown in FIG. **6** is adopted.

[0050] Accordingly, even in the vicinity of the top end of the first liquid-crystal driving electrode, the rotating direction of the liquid crystal molecules due to the action of the liquid-crystal driving electric field can be controlled in such a way as to accord with the ordinary rotating direction (i.e., the normal rotating direction). As a result, in the lateral electric field type LCD device including the reverse-rotation domain preventing structure using the first floating electrode, the generation of the reverse rotation domain can be surely prevented in the vicinity of the top end of the first liquid-crystal driving electrode.

[0051] Moreover, since the generation of the reverse rotation domain can be surely prevented in the above-described manner, a LCD device having improved image quality and improved reliability compared with the prior-art LCD device is obtainable.

[0052] In a preferred embodiment of the device according to the present invention, supposing that the first floating electrode and the comb-tooth-like part of the first liquid-crystal driving electrode overlapped therewith are unified, the first floating electrode and the comb-tooth-like part of the first liquid-crystal driving electrode assume an approximately L-like bent shape; and

[0053] a rotation direction obtained by tracing the bent shape from the top end of the first floating electrode to the comb-tooth-like part of the first liquid-crystal driving electrode by way of the overlapped part is in accordance with a normal rotation direction of the molecules of the liquid crystal.

[0054] In this embodiment, there is an advantage that the effects of the present invention are obtainable more surely.

[0055] In another preferred embodiment of the device according to the present invention, an electrically isolated second floating electrode is additionally provided in a vicinity of a bottom end of the comb-tooth-like part of the second liquid-crystal driving electrode (e.g., the common electrode);

[0056] wherein the second floating electrode comprises an overlapped part which is overlapped with the bottom end by way of an insulating film; and

[0057] a capacitance intervening between the second floating electrode and the second liquid-crystal driving electrode is greater than a capacitance intervening between the second floating electrode and the first liquid-crystal driving electrode.

[0058] In this embodiment, the electrically isolated second floating electrode is additionally provided in the vicinity of the bottom end of the comb-tooth-like part of the second liquid-crystal driving electrode. Thus, when a voltage is applied between the first and second liquid-crystal driving electrodes to generate the liquid-crystal driving electric field and exert the electric field on the liquid crystal, the electric potential of the second floating electrode is closer to the electric potential of the second liquid-crystal driving electrode than the electric potential of the first liquid-crystal driving electrode. Therefore, even in the vicinity of the bottom end of the second liquid-crystal driving electrode, the rotating direction of the liquid crystal molecules due to the action of the liquid-crystal driving electric field can be controlled in such a way as to accord with the ordinary rotating direction (i.e., the normal rotating direction). As a result, there is an advantage that the image quality and reliability is improved furthermore.

[0059] In this embodiment, it is preferred that the second floating electrode is located on a different layer from that of the first floating electrode. In this case, there is an additional advantage that the capacitance intervening between the first floating electrode and the first liquid-crystal driving electrode can be made easily greater than the capacitance intervening between the first floating electrode and the second liquid-crystal driving electrode according to the presence or absence of the insulating film.

[0060] In still another preferred embodiment of the device according to the present invention, an electrically isolated third floating electrode is additionally provided in a vicinity of a top end of the comb-tooth-like part of the second liquid-crystal driving electrode (e.g., the common electrode);

[0061] wherein the third floating electrode comprises an overlapped part which is overlapped with the top end by way of an insulating film; and

[0062] a capacitance intervening between the third floating electrode and the second liquid-crystal driving electrode is greater than a capacitance intervening between the third floating electrode and the first liquid-crystal driving electrode.

[0063] In this embodiment, the electrically isolated third floating electrode is additionally provided in the vicinity of the top end of the comb-tooth-like part of the second liquid-crystal driving electrode. Thus, even in the vicinity of the top end of the second liquid-crystal driving electrode, the rotating direction of the liquid crystal molecules due to the action of the liquid-crystal driving electric field can be controlled in such a way as to accord with the ordinary rotating direction (i.e., the normal rotating direction). Accordingly, the generation of the reverse rotation domain is surely prevented in the vicinity of the top end of the second liquid-crystal driving electrode also and as a result, there is an advantage that the image quality and reliability is improved furthermore.

[0064] In a further preferred embodiment of the device according to the present invention, an electrically isolated fourth floating electrode is additionally provided in a vicinity of a bottom end of the comb-tooth-like part of the first liquid-crystal driving electrode (e.g., the pixel electrode);

[0065] wherein the fourth floating electrode comprises an overlapped part which is overlapped with the bottom end by way of an insulating film; and

[0066] a capacitance intervening between the fourth floating electrode and the first liquid-crystal driving electrode is greater than a capacitance intervening between the fourth floating electrode and the second liquid-crystal driving electrode.

[0067] In this embodiment, the electrically isolated fourth floating electrode is additionally provided in the vicinity of the bottom end of the comb-tooth-like part of the first liquid-crystal driving electrode. Thus, even in the vicinity of the bottom end of the first liquid-crystal driving electrode, the rotating direction of the liquid crystal molecules due to the action of the liquid-crystal driving electric field can be controlled in such a way as to accord with the ordinary rotating direction (i.e., the normal rotating direction). Accordingly, there is an advantage that the image quality and reliability is improved furthermore.

[0068] In a still further preferred embodiment of the device according to the present invention, the second liquid-crystal driving electrode (e.g., the common electrode) comprises a protruding part in a vicinity of a bottom end of the comb-tooth-like part thereof; and

[0069] the protruding part is formed by protruding the comb-tooth-like part of the second liquid-crystal driving electrode toward the comb-tooth-like part of the first liquid-crystal driving electrode.

[0070] In this embodiment, there is an advantage that even if an additional floating electrode is not provided in the vicinity of the bottom end of the comb-tooth-like part of the second liquid-crystal driving electrode, a similar effect to that obtained by providing the additional floating electrode is obtainable.

[0071] In a still further preferred embodiment of the device according to the present invention, a common bus line electrically connected to the second liquid-crystal driving electrode (e.g., the common electrode) is additionally provided;

[0072] wherein the common bus line comprises a protruding part formed to protrude toward a top end of the comb-tooth-like part of the second liquid-crystal driving electrode.

[0073] In this embodiment, there is an advantage that even if an additional floating electrode is not provided in the vicinity of the top end of the comb-tooth-like part of the second liquid-crystal driving electrode, a similar effect to that obtained by providing the additional floating electrode is obtainable.

[0074] In a still further preferred embodiment of the device according to the present invention, a source electrode of a thin-film transistor is additionally provided, the source electrode being electrically connected to the first liquid-crystal driving electrode (e.g., the pixel electrode);

[0075] wherein the source electrode comprises a protruding part formed to protrude toward a bottom end of the comb-tooth-like part of the first liquid-crystal driving electrode.

[0076] In this embodiment, there is an advantage that even if an additional floating electrode is not provided in the vicinity of the bottom end of the comb-tooth-like part of the first liquid-crystal driving electrode, a similar effect to that obtained by providing the additional floating electrode is obtainable.

[0077] In a still further preferred embodiment of the device according to the present invention, the region where images are displayed by applying the liquid-crystal driving electric field to the liquid crystal is divided by a dividing line or a borderline into a first subregion including a thin-film transistor and a second subregion not including a thin-film transistor; and

[0078] the first and second subregions are bent to have an approximately V-like shape or form.

[0079] In this embodiment, since the rotation directions of the liquid crystal molecules in the first and second subregions can be set to be different from each other, there is an advantage that the display coloring due to the change of the viewing angle can be restrained.

BRIEF DESCRIPTION OF THE DRAWINGS

[0080] In order that the present invention may be readily carried into effect, it will now be described with reference to the accompanying drawings.

[0081] FIG. **1** is a partial plan view showing the schematic structure of a prior-art LCD device.

[0082] FIG. **2**A is a partial cross-sectional view along the line IIA-IIA in FIG. **1**.

[0083] FIG. **2**B is a partial cross-sectional view along the line IIB-IIB in FIG. **1**.

[0084] FIGS. **3**A and **3**B are partial plan views showing the process steps of a fabrication method of the prior-art LCD device of FIG. **1**, respectively.

[0085] FIGS. **4**A and **4**B are partial plan views showing the process steps of the fabrication method of the prior-art LCD device of FIG. **1**, respectively, which are subsequent to the steps of FIGS. **3**A and **3**B.

[0086] FIG. **5** is an enlarged partial plan view of the pixel electrode and the common electrode of the prior-art LCD device of FIG. **1**, showing the state of the liquid-crystal driving electric field.

[0087] FIG. **6** is an enlarged partial plan view of the pixel electrode and the common electrode of another prior-art LCD device, showing the state of the liquid-crystal driving electric field.

[0088] FIG. **7** is an enlarged partial plan view of the pixel electrode and the common electrode of still another prior-art LCD device.

[0089] FIG. **8** is an enlarged partial plan view of the pixel electrode and the common electrode of the prior-art LCD device of FIG. **7**, showing the state of the liquid-crystal driving electric field.

[0090] FIG. **9** is an enlarged partial plan view of the pixel electrode and the common electrode of a LCD device, showing the basic concept of the present invention.

[0091] FIG. **10** is an enlarged partial plan view of the pixel electrode and the common electrode of the LCD device according to the basic concept of the present invention, showing the state of the liquid-crystal driving electric field.

[0092] FIG. **11**A is a partial plan view showing the schematic structure of a LCD device according to a first embodiment of the present invention.

[0093] FIG. **11**B is a partial cross-sectional view along the line XIB-XIB in FIG. **11**A.

[0094] FIGS. **12**A and **12**B are partial plan views showing the process steps of a fabrication method of the LCD device according to the first embodiment of the present invention, respectively.

[0095] FIGS. **13**A and **13**B are partial plan views showing the process steps of the fabrication method of the LCD device according to the first embodiment of the present invention, respectively, which are subsequent to the steps of FIGS. **12**A and **12**B.

[0096] FIG. **14** is an enlarged partial plan view of the pixel electrode and the common electrode of the LCD device according to the first embodiment of the present invention, showing the state of the liquid-crystal driving electric field.

[0097] FIG. **15** is an enlarged partial plan view showing the electrode and the common electrode of a LCD device according to a second embodiment of the present invention.

[0098] FIG. **16**A is a partial plan view showing the schematic structure of a LCD device according to a third embodiment of the present invention.

[0099] FIG. **16**B is a partial plan view showing the source electrode of the LCD device according to the third embodiment of the present invention.

[0100] FIG. **16**C is a partial plan view showing the common bus line of the LCD device according to the third embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0101] Preferred embodiments of the present invention will be described in detail below while referring to the drawings attached.

Basic Concept of the Present Invention

[0102] First, the basic concept of the present invention is explained below with reference to FIGS. **9** and **10**. FIG. **9** is an enlarged partial plan view showing the schematic structure of the pixel electrode and the common electrode of a lateral electric field type LCD device according to the invention. FIG. **10** is an enlarged partial plan view showing the state of the liquid-crystal driving electric field (i.e., the electric lines of force) generated between the pixel and common electrodes of the said device. FIGS. **9** and **10** show the structure and the electric field in one of the pixel regions, respectively.

[0103] Similar to the prior-art structure shown in FIG. **7**, the structure of FIG. **9** comprises a pixel electrode **71** having two comb-tooth-like parts **71***a* and a common electrode **72** having one comb-tooth-like parts **72***a*. The comb-tooth-like parts **71***a* and **72***a* are mated or engaged with each other. Each of the pixel electrode **71** and the common electrode **72** serve as a liquid-crystal driving electrode.

[0104] Moreover, as the reverse-rotation domain preventing structure, floating electrodes **81**, each of which is made of an electrically isolated conductor, are provided in the vicinities of the top ends of the respective comb-tooth-like parts **71***a* of the pixel electrode **71**. Each of the floating electrodes **81**, which has an approximately V-like shape, comprises two arms formed by bending a thin belt. One of the arms of the electrode **81** is overlapped with the corresponding comb-tooth-like part **71***a* at a predetermined length from the top end of the said part **71***a*, forming an overlapped part Si. Here, the width of the overlapped part Si is set to be approximately equal to the width of the part **71***a*. The non-overlapped part of the electrode **81**, which corresponds to the other arm of the said electrode **81**, is inclined toward the opposite direction to the initial alignment direction (see the arrow in FIG. **9**) of the liquid crystal molecules with respect to the running direction (i.e., the vertical direction in FIG. **9**) of the comb-tooth-like part **71***a*. Each of the floating electrodes **80** is electrically insulated from the corresponding comb-tooth-like part **71***a* by an intervening insulating film (not shown). The intervening insulating film corresponds to the protective insulating film **59** and the organic interlayer film **60** in FIGS. **11**A and **11**B in the first embodiment explained later. Each of the floating electrodes **80** is electrically insulated from the common electrode **72** (and other electrodes not shown) also. Thus, each of the floating electrodes **80** is electrically isolated.

[0105] Each floating electrode **80** having the above-described structure is formed and arranged in such a way that the capacitance (the floating electrode-pixel electrode capacitance) C**1** intervening between the floating electrode **80** and the comb-tooth-like part **71***a* of the corresponding pixel electrode **71** by way of the intervening insulating film is greater than the capacitance (the floating electrode-common electrode capacitance) C**2** intervening between the floating electrode **80** and the common electrode **72**. Concretely speaking, it is preferred that the floating electrode-pixel electrode capacitance C**1** is twice as much as the floating electrode-common electrode capacitance C**2** or greater, in consideration of the effects or advantages of the present invention. It is more preferred that the capacitance C**1** is fifth times as much as the capacitance C**2** or greater, and further preferred that the capacitance C**1** is ten times as much as the capacitance C**2** or greater.

[0106] Such the magnitude relationship as above between the capacitances C**1** and C**2** can be easily realized by appropriately setting the area of the overlapped part S1 between the floating electrode **81** and the corresponding pixel electrode **71** and at the same time, forming the floating electrode **81** and the corresponding pixel electrode **71** not to be overlapped or minimizing the area of the overlapped part between the floating electrode **81** and the common electrode

72. In the structure of FIG. **9**, the floating electrode **81** and the common electrode **72** are formed not to have any overlapped part. In addition, since the thickness and dielectric constant of the insulating film intervening between the floating electrode **81** and the corresponding pixel electrode **71** are elements that determine the capacitances C**1** and C**2**, it is preferred that these elements are taken into consideration. This is because a desired relationship between the capacitances C**1** and C**1** can be realized more easily.

[**0107**] FIG. **10** shows the state of the liquid-crystal driving electric field generated by applying a voltage between the pixel electrode **71** and the common electrode **72** having the structure shown in FIG. **9**. In FIG. **10**, the state of the electric lines of force of the liquid-crystal driving electric field is shown by broken lines. With the structure of FIG. **9**, the electric potential of the floating electrode **81** under application of a voltage between the pixel electrode **71** and the common electrode **72** is determined by the ratio of the magnitude of the floating electrode-pixel electrode capacitance C**1** and that of the floating electrode-common electrode capacitance C**2**. For example, if the magnitude of the capacitance C**1** is 10 times as much as that of the capacitance C**2**, the electric potential of the floating electrode **81** has a value obtained by internally dividing the electric potentials of the pixel and common electrodes **71** and **72** at a ratio of 1:(10+1)=1:11. This means that the electric potential of the floating electrode **81** is extremely closer to the electric potential of the pixel electrode **71**. In addition, even if the values of the capacitances C**1** and C**2** are varied by the change of the alignment state of the liquid crystal molecules due to the change of the applied liquid-crystal driving electric field in accordance with the image signal, the floating electrode-pixel electrode capacitance C**1** is preferably kept to have a sufficiently larger value than that of the floating electrode-common electrode capacitance C**2**.

[**0108**] With the structure of FIG. **9**, as explained above, the electric potential of the floating electrode **81** is close to the electric potential of the pixel electrode **71**, which varies according to the magnitude ratio between the capacitances C**1** and C**2**. Therefore, the liquid-crystal driving electric field in the vicinity of the top end of the floating electrode **81** is similar to that obtained in the case where the prior-art electrode structure shown in FIG. **6** is adopted (where the top end of the comb-tooth-like part **171***a* of each pixel electrode **171** is bent). As a result, because of the same reason as the prior-art electrode structure shown in FIG. **6**, the generation of the reverse-rotation domain can be suppressed and minimized.

[**0109**] Moreover, with the prior-art electrode structure shown in FIG. **6**, since the pixel electrode **171** and the common electrode **172** are made of the same transparent electrode material formed on the same layer, the electrodes **171** and **172** need to be apart from each other to a certain extent to avoid electrical short-circuit between them. On the other hand, with the electrode structure of the present invention shown in FIG. **9**, since the floating electrodes **81** are located to be adjacent to the corresponding pixel electrodes **71** by way of the intervening insulating film, the pixel and common electrodes **71** and **72** can be made of a different electrode material from that of the floating electrodes **81**, which is formed on a different layer from that of the floating electrodes **81**. Accordingly, without increasing the failure possibility induced by inter-electrode short circuit, the floating electrode **81** giving an electric potential close to that of the pixel corresponding electrode **71** can be extended to the vicinity of the common electrode **72**. As a result, the region where the reverse rotation domain occurs can be reduced furthermore compared with the prior-art electrode structure shown in FIG. **6**. This means that uniform and stable display can be realized.

[**0110**] In this way, with the electrode structure of the present invention shown in FIG. **9**, not only better image quality than the prior-art is obtainable but also a LCD device with an improved reliability is realizable.

[**0111**] Since the basic concept of the present invention is explained above, preferred embodiments of the invention will be explained below.

First Embodiment

[**0112**] FIGS. **11**A and **11**B show the structure of a lateral electric field type active-matrix addressing LCD device according to a first embodiment of the present invention. FIG. **11**A is a partial plan view of the device, FIG. **11**B is a partial cross-sectional view along the line XIB-XIB in FIG. **11**A, FIGS. **12**A and **12**B and FIGS. **13**A and **13**B are partial plan views showing the process steps of the fabrication method of the LCD device according to the first embodiment, respectively. All of these figures show the structure of one pixel region.

[**0113**] With this LCD device, as shown in FIGS. **11**A and **12**B, rectangular regions are formed by gate bus lines **55** extending along the horizontal direction of FIGS. **11**A and **12**B and drain bus lines **56** extending along the vertical direction thereof. Pixel regions are formed in the respective rectangular regions. Pixels (and the pixel regions) are arranged in a matrix array as a whole. Common bus lines **53** are formed to extend along the horizontal direction of FIGS. **11**A and **12**B, similar to the gate bus lines **55**. At the respective intersections of the gate and drain bus lines **55** and **56**, TFTs **45** are formed to correspond to the respective pixels. The drain electrode **41**, the source electrode **42**, and the semiconductor film **43** of each TFT **45** are formed to have the patterns (shapes) shown in FIG. **12**B, respectively.

[**0114**] The pixel electrode **71** and the common electrode **72**, which generate a liquid-crystal driving electric field, have the shapes or patterns shown in FIG. **11**A. Specifically, the common electrode **72** comprises a frame-like main part formed to surround the said pixel region, and a comb-tooth-like part (i.e., a thin belt-shaped part protruding downward in the said pixel region) **72***a* extending from the middle of the upper side of the main part toward the lower side thereof in the inner space of the main part. The main part of the common electrode **72** is unified with the main parts of the common electrodes (not shown) for the other pixel regions. The lower (top) end of the comb-tooth-like part **72***a* is not contacted with the lower side thereof. On the other hand, the pixel electrode **71** is located in the rectangular inner space of the common electrode **72**. The pixel electrode **71** comprises a rectangular plate-like main part formed to be overlapped with the source electrode **42**, and two comb-tooth-like parts (i.e., two thin belt-shaped parts protruding upward in the said pixel region) **71***a* extending respectively from the two ends of the lower side of the main part toward the upper side thereof. These comb-tooth-like parts **71***a* are arranged at each side of the comb-tooth-like part **72***a* of the common electrode **72**. Therefore, the parts **71***a* and **72***a* are laid out in such a way as to be mated or engaged with each other in the said pixel region. The intervals between the comb-tooth-like part **72***a* and the comb-tooth-like parts **72***a* at each side thereof are approximately equal to the intervals between the respective comb-tooth-like parts **71***a* and the main part of the common electrode **72**.

[0115] The (main part of the) pixel electrode **71** is electrically connected to the corresponding source electrode **42** of the TFT **45** by way of the corresponding contact hole **61** that penetrates through an organic interlayer film **60** and a protective insulating film **59**. The (main part of the) common electrode **72** is electrically connected to the corresponding common bus line **53** by way of the corresponding contact hole **62** that penetrates through the organic interlayer film **60**, the protective insulating film **59**, and an interlayer insulating film **57**. Their connection states are the same as those of the prior-art LCD device shown in FIG. **2**A and therefore, the figure showing them is omitted here. Part of the source electrode **42** of the TFT **45** is overlapped with the corresponding common bus line **53** by way of the interlayer insulating film **57**, thereby forming a storage capacitor for the said pixel region by the said overlapped part.

[0116] At the top and bottom ends of the respective comb-tooth-like parts **71***a* of the pixel electrode **71**, electrically isolated floating electrodes **81** are provided, respectively. These floating electrodes **81** are located in a lower layer than that of the pixel electrode **71**, as clearly shown in FIG. **11**B, where the organic interlayer film **60** and the protective insulating film **59** intervene between the floating electrodes **81** and the pixel electrode **71**. The floating electrodes **81** have an approximately L-like shape, as shown in FIG. **12**B, which consists of a part extending laterally and a part extending vertically.

[0117] The vertically extending part of the floating electrode **81**, which is located near the top end of the comb-tooth-like part **71***a* of the pixel electrode **71**, is overlapped with the said part **71***a* almost entirely, thereby forming an overlapped part S**1**. The horizontally extending part of the said floating electrode **81** is not overlapped with the said part **71***a*. The non-overlapped part of the said floating electrode **81** protrudes horizontally to the left side from the said top end of the part **71***a*. The said floating electrode **81** protrudes toward the left side from the extending direction of the part **71***a* (i.e., the vertical direction in FIG. **11**A) while setting the overlapped part S**1** as the origin. As a result, supposing that the floating electrode **81** and the corresponding comb-tooth-like part **71***a* are unified, the floating electrode **81** and the corresponding comb-tooth-like part **71***a* assume an approximately L-like bent shape. Moreover, the rotation direction obtained by tracing the bent shape from the top end of the floating electrode **81** to the bottom end of the part **71***a* by way of the overlapped part S**1** is clockwise, which is in accordance with the normal rotation direction of the liquid crystal molecules **21** (here, clockwise). See the thick arrow in FIG. **11**A.

[0118] The vertically extending part of the floating electrode **81** located near the bottom end of the comb-tooth-like part **71***a* of the pixel electrode **71** is similar to that located near the top end of the part **71***a* as described above. Specifically, the vertically extending part of the floating electrode **81**, which is located near the bottom end of the comb-tooth-like part **71***a*, is overlapped with the said part **71***a*, thereby forming an overlapped part S**1**'. The horizontally extending part of the said floating electrode **81** is not overlapped with the said part **71***a*. The non-overlapped part of the said floating electrode **81** protrudes-horizontally to the right side from the said bottom end of the part **71***a*. The said floating electrode **81** protrudes toward the right side from the extending direction of the part **71***a* (i.e., the vertical direction in FIG. **11**A) while setting the overlapped part S**1**' as the origin. As a result, supposing that the floating electrode **81** and the corresponding comb-tooth-like part **71***a* are unified, the floating electrode **81** and the comb-tooth-like part **71***a* assume an approximately L-like bent shape. Moreover, the rotation direction obtained by tracing the bent shape from the top end of the floating electrode **81** to the top end of the part **71***a* by way of the overlapped part S**1**' is clockwise as well, which is in accordance with the normal rotation direction of the liquid crystal molecules **21**.

[0119] At the top and bottom ends of the respective comb-tooth-like parts **72***a* of the common electrode **72**, electrically isolating floating electrodes **82** are provided, respectively. These floating electrodes **82** are located in a lower layer than that of the common electrode **72**, as shown in FIG. **11**B, where the organic interlayer film **60**, the protective insulating film **59**, and the interlayer insulating film **57** intervene between the floating electrodes **82** and the common electrode **72**. The floating electrodes **82** have an approximately L-like shape, as shown in FIG. **12**A, which consists of a part extending laterally and a part extending vertically. Here, the shape of the floating electrodes **82** is the same as that of the floating electrodes **81**.

[0120] The vertically extending part of the floating electrode **82**, which is located near the top end of the comb-tooth-like part **72***a* of the common electrode **72**, is overlapped with the said part **72***a*, thereby forming an overlapped part S**2**. The horizontally extending part of the said floating electrode **82** is not overlapped with the said part **72***a*. The non-overlapped part of the said floating electrode **82** protrudes horizontally to the right side from the said top end of the part **72***a*. The said floating electrode **82** protrudes toward the right side from the extending direction of the part **72***a* while setting the overlapped part S**2** the origin. As a result, supposing that the floating electrode **82** and the corresponding comb-tooth-like part **72***a* are unified, the floating electrode **82** and the comb-tooth-like part **72***a* assume an approximately L-like bent shape. Moreover, the rotation direction obtained by tracing the bent shape from the top end of the floating electrode **82** to the bottom end of the part **72***a* by way of the overlapped part S**2** is clockwise, which is in accordance with the normal rotation direction of the liquid crystal molecules **21**.

[0121] The vertically extending part of the floating electrode **82** located near the bottom end of the comb-tooth-like part **72***a* of the common electrode **72** is similar to that located near the top end of the part **72***a* as described above. Specifically, the vertically extending part of the floating electrode **82**, which is located near the bottom end of the comb-tooth-like part **72***a*, is overlapped with the said part **72***a*, thereby forming an overlapped part S**2**'. The horizontally extending part of the said floating electrode **82** is not overlapped with the said part **72***a*. The non-overlapped part of the said floating electrode **82** protrudes horizontally to the left side from the said top end of the part **72***a*. The said floating electrode **82** protrudes toward the left side from the extending direction of the part **72***a* while setting the overlapped part S2' as the origin. As a result, supposing that the floating electrode **82** and the corresponding comb-tooth-like part **72***a* are unified, the floating electrode **82** and the comb-tooth-like part **72***a* assume an approximately L-like bent shape. Moreover, the rotation direction obtained by tracing the bent shape from the top end of the floating electrode **82** to the top end of the part **72***a* by way of the overlapped part S2' is clockwise as well, which is in accordance with the normal rotation direction of the liquid crystal molecules **21**.

[0122] At the inner positions near the upper right corner and the lower left corner of the main part of the common electrode **72** also, electrically isolating floating electrodes **82** are provided, respectively. These floating electrodes **82** are located in a lower layer than the common electrode **72**, where the organic interlayer film **60**, the protective insulating film **59**, and the interlayer insulating film **57** intervene between the floating electrodes **82** and the common electrode **72**. The floating electrodes **82** have an approximately L-like shape, as shown in FIG. **12**A, which consists of a part extending laterally and a part extending vertically. Here, the shape of the floating electrodes **82** is the same as that of the above-described floating electrodes **82**.

[0123] The vertically extending part of the floating electrode **82** located at the inner position near the upper right corner of the main part of the common electrode **72** is overlapped with the said main part, thereby forming an overlapped part S2'". The horizontally extending part of the said floating electrode **82** is not overlapped with the said main part. The non-overlapped part of the said floating electrode **82** protrudes horizontally to the left side from the said main part. The said floating electrode **82** protrudes toward the left side from the extending direction of the said main part while setting the overlapped part S2" as the origin. As a result, supposing that the said floating electrode **82** and the said main part are unified, they assume an approximately L-like bent shape. Moreover, the rotation direction obtained by tracing the bent shape from the top end of the floating electrode **82** to the bottom end of the main part by way of the overlapped part S2" is clockwise, which is in accordance with the normal rotation direction of the liquid crystal molecules **21**.

[0124] The vertically extending part of the floating electrode **82** is located at the inner position near the lower left corner of the main part of the common electrode **72** is overlapped with the said main part, thereby forming an overlapped part S2". This is similar to the above-described vertically extending part of the floating electrode **82** located at the inner position near the upper right corner of the main part of the common electrode **72**. The horizontally extending part of the said floating electrode **82** is not overlapped with the said main part. The non-overlapped part of the said floating electrode **82** protrudes horizontally to the right side from the said main part. The said floating electrode **82** protrudes toward the right side from the extending direction of the said main part while setting the overlapped part S2'" as the origin. As a result, supposing that the said floating electrode **82** and the said main part are unified, they assume an approximately L-like bent shape. Moreover, the rotation direction obtained by tracing the bent shape from the top end of the floating electrode **82** to the bottom end of the main part by way of the overlapped part S2" is clockwise, which is in accordance with the normal rotation direction of the liquid crystal molecules **21**.

[0125] The cross-sectional structure of the LCD device according to the first embodiment is shown in FIG. **11**B, where the device is configured by coupling and unifying an active-matrix substrate and an opposite substrate to sandwich a liquid crystal between them.

[0126] The active-matrix substrate comprises a transparent glass plate **11**; and the common bus lines **53**, the gate bus lines **55**, the drain bus lines **56**, the TFTs **45**, the pixel electrodes **71**, the common electrode **72**, and the floating electrodes **81** and **82**, all of which are formed on or over the Inner surface of the glass plate **11**. The common bus lines **53**, the gate bus lines **155**, and the floating electrodes **82**, which are directly formed on the inner surface of the glass plate **11**, are covered with the interlayer insulating film **57**. The drain electrodes **41**, the source electrodes **42**, and the semiconductor films **43** of the TFTs **45**, the drain bus lines **56**, and the floating electrodes **81** are formed on the interlayer insulating film **57**. Thus, the common bus lines **53**, the gate bus lines **55**, and the floating electrodes **82** are electrically insulated from the drain electrodes **41**, the source electrodes **42**, the semiconductor films **43**, the drain bus lines **56**, and the floating electrodes **81** by the interlayer insulating film **57**. These structures formed on the glass plate **11** are covered with the protective insulating film **59** except for the regions where the contact holes **61** and **62** are formed. The level differences caused by the contact holes **61** and **62** are planarized by the organic interlayer film **60** formed on the protective insulating film **59**. The pixel electrodes **71** and the common electrode **72** are formed on the organic interlayer film **60**. As explained above, the pixel electrode **71** is electrically connected to the corresponding source electrode **42** by way of the corresponding contact hole **61**, and the common electrode **72** is electrically connected to the corresponding common bus line **53** by way of the corresponding contact hole **62**. In addition, the cross-sectional view of FIG. **11**B is schematically drawn and thus, it does not reproduce the actual level differences faithfully.

[0127] The surface of the active matrix substrate having the above-described structure, on which the pixel electrodes **71** and the common electrode **72** are formed, is covered with an alignment film **31** formed by an organic polymer film. The surface of the alignment film **31** has been subjected to an alignment treatment for directing the initial orientation direction of the liquid crystal molecules **21** to a desired direction (see the arrow in FIG. **11**A).

[0128] On the other hand, the opposite substrate comprises a transparent glass plate **12**; and a color filter (not shown) including the three primary colors of R, G and B, and a light-shielding black matrix (not shown) formed in the regions other than those corresponding to the respective pixel regions, both of which are formed on the Inner surface of the glass plate **12**. The color filter and the black matrix are covered with an acrylic-based overcoat film (not shown). On the inner surface of the overcoat film, columnar spacers (not shown) are formed to control the interval between the active-matrix substrate and the opposite substrate. The inner surface of the overcoat film is covered with an alignment film **32** formed by an organic polymer film. The surface of the alignment film **32** has been subjected to an alignment treatment for directing the initial orientation direction of the liquid crystal molecules **21** to a desired direction (see the arrow in FIG. **11**A).

[**0129**] The active-matrix substrate and the opposite substrate each having the above-described structure are superposed on each other at a predetermined interval in such a way that their surfaces on which the alignment films **31** and **32** are directed inward and opposed to each other. A liquid crystal **20** is introduced into the gap between the both substrates. The peripheries of the substrates are sealed by a sealing member (not shown) to confine the liquid crystal **20** therein. A pair of polarizer plates is arranged on the outer surfaces of the substrates, respectively.

[**0130**] The surfaces of the alignment films **31** and **32** are uniformly alignment-treated in such a way that the liquid crystal molecules **21** are aligned along the desired direction when no electric field is applied, as described above. The alignment direction by the alignment treatments is a direction inclined clockwise by 15° with respect to the direction along which the comb-tooth parts **71***a* and **72***a* of the pixel and common electrodes **71** and **72** are extended (i.e., the vertical direction in FIG. **11**A).

[**0131**] The transmission axes of the pair of polarizer plates are crossed at right angles. The transmission axis of one of the pair of polarizer plates is in accordance with the initial alignment direction of the liquid crystal molecules determined by the uniform alignment treatment.

[**0132**] Since each of the floating electrodes **81** provided for the pixel electrodes **71** is opposed to the corresponding comb-tooth-like part **71***a* of the pixel electrode **71** by way of the protective insulating film **59** and the organic interlayer film **60**, it has a capacitance (the floating electrode-pixel electrode capacitance) C**1** with respect to the pixel electrode **71**. Moreover, since the said floating electrodes **81** is opposed to (the main part and the comb-tooth-like part **72***a* of) the corresponding common pixel electrode **72** by way of the protective insulating film **59** and the organic interlayer film **60**, it has a capacitance (the floating electrode-common electrode capacitance) C**2** with respect to the common electrode **72**. As seen from FIG. **11**B, the distance between the floating electrode **81** and the pixel electrode **71** is set to be smaller than that between the floating electrode **81** and the common electrode **72** and therefore, it is apparent that these capacitances C**1** and C**2** have a relationship of C**1**>C**2**. By adjusting the relationship between the areas of the overlapped parts S**1** and S**1**' and adjusting the thickness and/or dielectric constant of the protective insulating film **59** and the organic interlayer film **60** located between the floating electrode **81** and the pixel electrode **71**, as already explained in BASIC CONCEPT OF THE PRESENT INVENTION, the value of C**1** is preferably set to be twice as much as that of C**2** or greater. It is more preferred that the value of C**1** is five times as much as that of C**2** or greater. It is still more preferred that the value of C**1** is ten times as much as that of C**2** or greater.

[**0133**] By setting the magnitude ratio of the capacitances C**1** and C**2** to be C**1**>C**2**, the electric potential of the floating electrode **81** can be made close to the electric potential of the pixel electrode **71**. Thus, the state of the liquid-crystal driving electric field generated in the vicinity of the top end of the comb-tooth-like part **71***a* of the pixel electrode **71** is similar to that obtained in the case where the prior-art electrode structure of FIG. **6** is adopted (i.e., the structure that the end of the comb-tooth-like part **171***a* of the pixel electrode **171** is bent is adopted). Accordingly, because of the same reason as for the prior-art electrode structure, the generation of the reverse rotation domain can be effectively restrained in the vicinity of the top end of each comb-tooth-like part **71***a*. In addition, by setting the value of C**1** is five times or ten times as much as that of C**2** or greater, the generation of the reverse rotation domain can be minimized.

[**0134**] The above explanation for the floating electrodes **81** is applied to the floating electrodes **82** provided for the common electrode **72**. Specifically, since each of the floating electrodes **82** is opposed to the corresponding comb-tooth-like part **72***a* or main part of the common electrode **72** by way of the interlayer insulating film **57**, the protective insulating film **59**, and the organic interlayer film **60**, it has a capacitance (the floating electrode-common electrode capacitance) C**3** with respect to the common electrode **72**. Moreover, since the said floating electrodes **82** is opposed to (the main part or the comb-tooth-like part **71***a* of) the corresponding pixel electrode **71** by way of interlayer insulating film **57**, the protective insulating film **59**, and the organic interlayer film **60**, it has a capacitance (the floating electrode-pixel electrode capacitance) C**4** with respect to the pixel electrode **71**. The capacitances C**3** and C**4** are set to have a relationship of C**3**>C**4**. As already explained in BASIC CONCEPT OF THE PRESENT INVENTION, it is preferred that the value of C**3** is twice as much as that of C**4** or greater, more preferred that the value of C**3** is five times as much as that of C**4** or greater, and still more preferred that the value of C**3** is ten times as much as that of C**4** or greater.

[**0135**] Such the magnitude relationship between C**3** and C**4** as above is realized by appropriately setting the areas of the overlapped parts S**2** and S**2**' and forming the floating electrode **82** not to be overlapped with the corresponding pixel electrode **71**. At that time, the thickness and/or dielectric constant of the interlayer insulating film **57**, the protective insulating film **59** and the organic interlayer film **60** located between the floating electrode **82** and the corresponding pixel electrode **71** in the overlapped parts S**2** and S**2**' also are taken into consideration.

[**0136**] By setting the magnitude ratio of the capacitances C**3** and C**4** to be C**3**>C**4**, the electric potential of the floating electrode **82** can be made close to the electric potential of the common electrode **72**. Thus, the state of the liquid-crystal driving electric field generated in the vicinity of the top end of the comb-tooth-like part **72***a* of the common electrode **72** is similar to that obtained in the case where the prior-art electrode structure of FIG. **6** is adopted (i.e., the structure that the end of the comb-tooth-like part **171***a* of the pixel electrode **171** is bent is adopted). Accordingly, because of the same reason as for the prior-art electrode structure, the generation of the reverse rotation domain can be effectively restrained in the vicinity of the top end of each comb-tooth-like part **72***a*.

[**0137**] In addition, the initial alignment direction (i.e., the alignment treatment direction) of the liquid crystal molecules **21** is a direction inclined clockwise by 15° with respect to the direction along which the comb-tooth parts **71***a* and **72***a* of the pixel and common electrodes **71** and **72** are extended (i.e., the vertical direction in FIG. **11**A). See the thick arrow in FIG. **11**A. For this reason, when a liquid-crystal driving electric field is applied to the liquid crystal molecules **21**, the molecules **21** will rotate clockwise (see the curved arrows in FIG. **11**A).

[0138] Next, the fabrication process steps of the LCD device according to the first embodiment shown in FIGS. **11**A and **11**B will be explained below with reference to FIGS. **12**A and **12**B and FIGS. **13**A and **13**B.

[0139] The active-matrix substrate is fabricated in the following way. First, a Cr film is formed on one of the surfaces of the glass plate **111** and patterned, thereby forming the common bus lines **53**, the gate bus lines **55**, and the floating electrodes **82** for the common electrodes **72**, each having the shapes of FIG. **12**A. Thereafter, the interlayer insulating film **57**, which is formed by a SiN_x film, is formed to cover the common bus lines **53**, the gate bus lines **55** and the floating electrodes **82** over the whole surface of the glass plate **11**. Subsequently, the semiconductor films **43** (which are usually formed by an a-Si film) are formed to have island-shaped patterns on the interlayer insulating film **57** in such a way as to be overlapped with the corresponding gate bus lines **55** by way of the interlayer insulating film **57**. A Cr film is formed on the interlayer insulating film **57** and is patterned, thereby forming the drain bus lines **56**, the drain electrodes **41**, the source electrodes **142**, and the floating electrodes **81** for the pixel electrode **71** (see FIG. **12**B). Thereafter, the protective insulating film **59** made of SiN_x and the organic interlayer film **60** made of photosensitive acrylic resin are successively stacked on the interlayer insulating film **57** in this order. Following this, the rectangular contact holes **61** penetrating through the protective insulating film **59** and the organic interlayer film **60** and the rectangular contact holes **62** penetrating through the interlayer insulating film **57**, the protective insulating film **59**, and the organic interlayer film **60** are formed (see FIG. **13**A). An ITO film, which is a transparent conductive material, is formed on the organic interlayer film **60** and patterned, thereby forming the pixel electrodes **71** and the common electrode **72** on the organic interlayer film **60**. The pixel electrodes **71** are in contact with the corresponding source electrodes **42** by way of the corresponding contact holes **61**. The common electrode **72** is in contact with the common bus lines **53** by way of the corresponding contact holes **62**). In this way, the active-matrix substrate is fabricated.

[0140] The opposite substrate (the color filer substrate) is fabricated in the following way. First, the color filter (not shown) and the light-shielding black matrix (not shown) are formed on the glass plate **12** and thereafter, the overcoat film (not shown) is formed to cover the color filter and the black matrix over the whole surface of the glass plate **12**. Then, the columnar spacers (not shown) are formed on the overcoat film. In this way, the opposite substrate is fabricated.

[0141] The alignment films **31** and **32**, which are made of polyimide, are formed on the surfaces of the active-matrix substrate and the opposite substrate fabricated as described above, respectively. Next, the surfaces of the alignment films **31** and **32** are uniformly alignment-treated. These two substrates are then superposed to have a constant interval (e.g. approximately 4.5 μm), and the peripheries of the substrates are sealed by the sealing member except for an injection hole for the liquid crystal. Next, in a vacuum chamber, a predetermined nematic liquid crystal (e.g., a p-type nematic liquid crystal whose refractive index anisotropy is 0.067) is injected into the gap between the substrates through the injection hole and thereafter, the injection hole is closed. After the substrates are coupled and unified in this way, the polarizer plates (not shown) are respectively adhered on the outer surfaces of the substrates. As a result, the LCD device according to the first embodiment shown in FIGS. **11**A and **11**B is completed.

[0142] An n-type nematic liquid crystal may be used. In this case, it is sufficient that only the alignment direction is made different by 90° with respect to the above-described angle while keeping the other elements the same. In the following explanation, a p-type is nematic liquid crystal is used.

[0143] Next, the operation of the LCD device according to the first embodiment will be explained below with reference to FIG. **14**. In FIG. **14**, the state of the liquid-crystal driving electric field generated by applying a voltage between the pixel electrode **71** and the common electrode **72** is shown by broken lines that denote the electrical lines of force of the electric field. The rotation direction of the liquid crystal molecules **21** due to the action of the liquid-crystal driving electric field is shown by curved arrows, also.

[0144] As described previously, the initial alignment direction of the liquid crystal molecules **21** is a direction inclined clockwise by **159** with respect to the direction along which the comb-tooth parts **71***a* and **72***a* of the pixel and common electrodes **71** and **72** are extended (i.e., the vertical direction in FIG. **11**A). Therefore, when the liquid-crystal driving electric field is applied, the molecules **21** are rotated clockwise in the ordinary regions. Moreover, as shown in FIG. **11**, because the floating electrodes **81** and **82** are respectively provided, the liquid-crystal driving electric field is inclined along the same direction in the vicinities of the top end of the comb-tooth-like part **71***a* of each pixel electrode **71** and the bottom end of the comb-tooth-like part **72***a* of each common electrode **72**. Thus, the molecules **21** are rotated clockwise similar to the ordinary regions, which means that the reverse rotation domain is refrained from being generated. As a result, not only improved image quality is obtainable but also an LCD device having improved reliability is realizable.

[0145] In addition, although the floating electrodes **81** are provided for the pixel electrodes **71** and the floating electrodes **82** are provided for the common electrode **72** in the first embodiment, the floating electrodes **82** may be omitted, if the magnitude ratio of the capacitances C**1** and C**2** can be set sufficiently large. This is applicable to the second and third embodiments explained below.

Second Embodiment

[0146] FIG. **15** is a similar drawing to FIG. **14**, which shows the feature of a LCD device according to a second embodiment. The second embodiment is the same in structure as the above-described first embodiment except that the floating electrodes **82** provided near the bottom end of the comb-tooth-like part **72***a* of the common electrode **72** and the upper right corner of the main part of the common electrode **72** thereof are omitted, and that an inclined protruding part **72***b* is provided at the bottom end of the part **72***a* and an inclined protruding part **72***c* is provided at the inner side of the upper right corner thereof instead. Therefore, the explanation about the same structure is omitted by attaching the same reference symbols as used in the first embodiment to the same elements.

[0147] Although not shown in FIG. **15**, the floating electrodes **82** are respectively provided near the top end of the comb-tooth-like part **72***a* of the common electrode **72** and the lower left corner of the main part of the common electrode **72** thereof, which is similar to the structure of the first embodiment (see FIG. **11**A).

[0148] In FIG. **15**, the protruding part **72***b* provided near the bottom end of the comb-tooth-like part **72***a* has a similar plan shape to the non-overlapped part (the part other than the overlapped part S2') of the floating electrode **82** with the common electrode **72**. By this structure, the electric potential of the protruding part **72***b* can be equalized to that of the common electrode **72**.

[0149] Moreover, the protruding part **72***c* provided near the inner side of the upper right corner of the common electrode **72** has a similar plan shape to the non-overlapped part (the part other than the overlapped part S2") of the floating electrode **82** with the common electrode **72**. By this structure, the electric potential of the protruding part **72***c* can be equalized to that of the common electrode **72**.

[0150] With the second embodiment, as explained above, the protruding parts **72***b* and **72***c* are provided for the common electrode **72**. Therefore, an approximately the same liquid-crystal driving electric field as the first embodiment is generated, which means that the reverse rotation domain is refrained from being generated in the same way as the first embodiment. As a result, not only improved image quality is obtainable but also an LCD device having improved reliability is realizable.

Third Embodiment

[0151] FIG. **16** shows a LCD device according to a third embodiment. The LCD device according to the third embodiment is the same in structure as the above-described first embodiment except that the pixel electrode and the common electrode that generate the liquid-crystal driving electric field are bent to intentionally make the driving (rotating) direction of the liquid crystal molecules different in the respective regions with the said bent parts of the pixel and common electrodes. This was created with reference to the technique disclosed in the previously cited Publication No. 10-307295. Therefore, the explanation about the same structure is omitted by attaching the same reference symbols as used in the first embodiment to the same elements.

[0152] With the third embodiment, as shown in FIG. **16**A, the pixel electrode **71** and the common electrode **72** that generate the liquid-crystal driving electric field comprise the comb-tooth-like parts **71***a* and **72** which are mated or engaged with each other, similar to the first embodiment. However, the comb-tooth-like parts **71***a* and **72** are bent to have an approximately V-like shape at an approximately center of the pixel region by a straight line L extending horizontally. Responsive to this, the drain bus lines **56** extending vertically are bent to have an approximately V-like shape, also. In this way, the shape of the said pixel region is bent to have an approximately V-like shape.

[0153] The said pixel region is divided into a first subregion **1** located above the line L and a second subregion **2** located below the line L. The pixel electrode **71** and the common electrode **72** are bent at a predetermined angle counterclockwise in the first subregion **1** and bent at the same angle as the first subregion **1** clockwise in the second subregion **2**. The alignment treatment direction of the liquid crystal molecules **21** is set to be parallel to the vertical direction in FIG. **16**A when no electric field is applied (see thick arrow in FIG. **16**A).

[0154] On the side of the said pixel region close to the TFT **45** (i.e., the lower side of FIG. **16**A), the floating electrodes **81** and **82** are omitted. Instead, in consideration of the reverse-rotation domain preventing structure disclosed in the previously cited Publication No. 2002-323706, the plan shapes of the source electrode **42** and the common bus line **53** are changed to those shown in FIGS. **16**B and **16**C, respectively. In other words, two protruding parts **42***a* each having an inclined side are formed at the inner side of the source electrode **42**, as shown in FIG. **168**. Two protruding parts **53***a* each having an inclined side are formed at the inner side of the common bus line **53**, as shown in FIG. **16**C. By the protruding parts **42***a* and **53***a*, the rotation direction of the liquid crystal molecules **21** near the protruding parts **42***a* and **53***a* when the liquid-crystal driving electric field is applied can be made along the arrows in the second subregion **2**.

[0155] Moreover, on the side of the said pixel region far from the TFT **45** (i.e. the upper side of FIG. **16**A), the structure is the same as the above-described second embodiment. Specifically, the floating electrodes **81** are respectively provided near the top ends of the two comb-tooth-like parts **71***a* of the pixel electrode **71**. The floating electrodes **82** are not provided near the bottom end of the comb-tooth-like part **72***a* of the common electrode **72** and the upper right corner of the main part of the common electrode **72** thereof. Instead, the Inclined protruding part **72***b* is provided at the bottom end of the part **72***a* and the inclined protruding part **72***c* is provided at the inner side of the upper right corner thereof.

[0156] With the third embodiment having the above-described structure, in the vicinities of the top ends of the comb-tooth-like parts **71***a* of the pixel electrode **71** and the bottom end of the comb-tooth-like part **72***a* of the common electrode **72** (which belong to the first subregion **1**), a similar inclined electric field to that of FIG. **14** is generated. In the vicinities of the bottom ends of the comb-tooth-like parts **71***a* of the pixel electrode **71** and the top end of the comb-tooth-like part **72***a* of the common electrode **72** (which belong to the second subregion **2**), a similar inclined electric field to that obtained by reversing the electric field of FIG. **14** with respect to the line L is generated. Therefore, the liquid crystal molecules **21** in the said pixel region are rotated clockwise or counterclockwise similar to the ordinary regions in the first and second subregions **1** and **2**. This means that the reverse rotation domain is effectively refrained from being generated. As a result, not only improved image quality is obtainable but also an LCD device having improved reliability is realizable.

[0157] The liquid-crystal driving electric field under application of the liquid-crystal driving voltage is slightly inclined counterclockwise in the first subregion **1** with respect to the horizontal direction (i.e. the direction of the line L) and slightly Inclined clockwise in the second subregion **2** with respect to the horizontal direction. Accordingly, the liquid crystal molecules **21**, which have been uniformly aligned along the vertical direction of FIG. **16**A when no electric field is applied, are rotated clockwise in the first subregion **1** and counterclockwise in the second subregion **2**, by the liquid-crystal driving electric field. In this way, because the rotation direction of the molecules **21** is different from each other in the first and second subregions **1** and **2**, there is an advantage that the display coloring due to the change of the viewing angle can be restrained.

Variations

[0158] The above-described first to third embodiments are preferred embodied examples of the present invention. Therefore, it is needless to say that the present invention is not limited to these embodiments. Any other modification is applicable to the embodiments.

[0159] For example, in the above-described embodiments of the invention, the floating electrodes provided near the comb-tooth-like part of the pixel or common electrode or the corner of the main part of the common electrode are formed to have an approximately L-like shape. However, they may be formed to have any other shape as necessary if the above-described relationship of the capacitances is satisfied.

[0160] Moreover, in the above-described embodiments of the invention, supposing that the floating electrode provided near the comb-tooth-like part of the pixel electrode and the comb-tooth-like part of the common electrode overlapped therewith are unified, they assume an approximately L-like bent shape. The rotation direction obtained by tracing the bent shape from the top end of the said floating electrode to the comb-tooth-like part of the pixel electrode by way of the overlapped part is in accordance with the normal rotation direction of the molecules of the liquid crystal. However, the shapes of the floating electrode and the comb-tooth-like part of the pixel electrode are not limited to these. If the rotation direction obtained by tracing the shape is in accordance with the normal rotation direction of the liquid crystal molecules, any other shape may be used.

[0161] Furthermore, in the above-described embodiments of the invention, the floating electrode for the common electrode is provided in addition to the floating electrode for the pixel electrode. However, the floating electrode or protruding part for the common electrode may be omitted if a desired magnitude ratio of the capacitances is obtained by providing only the floating electrode for the pixel electrode.

[0162] While the preferred forms of the present invention have been described, it is to be understood that modifications will be apparent to those skilled in the art without departing from the spirit of the invention. The scope of the present invention, therefore is to be determined solely by the following claims.

What is claimed is:

1. A lateral electric field type liquid-crystal display device comprising:

a first substrate and a second substrate arranged to be opposite to each other at an approximately constant interval;

a liquid crystal arranged between the first and second substrates; and

a first liquid-crystal driving electrode and a second liquid-crystal driving electrode, which are formed on one of the first and second substrates;

wherein an alignment direction of molecules of the liquid crystal is rotated in a plane approximately parallel to the first and second substrates to display images by applying a liquid-crystal driving electric field approximately parallel to the first and second substrates to the liquid crystal using the first and second liquid-crystal driving electrodes;

the first and second liquid-crystal driving electrodes comprise comb-tooth-like parts extending approximately parallel to each other and being meshed with each other, respectively, in a region where images are displayed by applying the liquid-crystal driving electric field to the liquid crystal;

an electrically isolated first floating electrode is provided in a vicinity of a top end of the comb-tooth-like part of the first liquid-crystal driving electrode, where the first floating electrode comprises an overlapped part which is overlapped with the top end by way of an insulating film; and

a capacitance intervening between the first floating electrode and the first liquid-crystal driving electrode is greater than a capacitance intervening between the first floating electrode and the second liquid-crystal driving electrode.

2. The device according to claim 1, wherein supposing that the first floating electrode and the comb-tooth-like part of the first liquid-crystal driving electrode overlapped therewith are unified, the first floating electrode and the comb-tooth-like part of the first liquid-crystal driving electrode assume an approximately L-like bent shape; and

a rotation direction obtained by tracing the bent shape from the top end of the first floating electrode to the comb-tooth-like part of the first liquid-crystal driving electrode by way of the overlapped part is in accordance with a normal rotation direction of the molecules of the liquid crystal.

3. The device according to claim 1, further comprising an electrically isolated second floating electrode provided in a vicinity of a bottom end of the comb-tooth-like part of the second liquid-crystal driving electrode:

wherein the second floating electrode comprises an overlapped part which is overlapped with the bottom end by way of an insulating film; and

a capacitance intervening between the second floating electrode and the second liquid-crystal driving electrode is greater than a capacitance intervening between the second floating electrode and the first liquid-crystal driving electrode.

4. The device according to claim 3, wherein the second floating electrode is located on a different layer from that of the first floating electrode.

5. The device according to claim 1, further comprising an electrically isolated third floating electrode provided in a vicinity of a top end of the comb-tooth-like part of the second liquid-crystal driving electrode;

wherein the third floating electrode comprises an overlapped part which is overlapped with the top end by way of an insulating film; and a capacitance intervening between the third floating electrode and the second liquid-crystal driving electrode is greater than a capacitance intervening between the third floating electrode and the first liquid-crystal driving electrode.

6. The device according to claim 1, further comprising an electrically isolated fourth floating electrode provided in a vicinity of a bottom end of the comb-tooth-like part of the first liquid-crystal driving electrode;

wherein the fourth floating electrode comprises an overlapped part which is overlapped with the bottom end by way of an insulating film; and

a capacitance intervening between the fourth floating electrode and the first liquid-crystal driving electrode is greater than a capacitance intervening between the fourth floating electrode and the second liquid-crystal driving electrode.

7. The device according to claim 1, wherein the second liquid-crystal driving electrode comprises a protruding part in a vicinity of a bottom end of the comb-tooth-like part thereof; and

the protruding part is formed by protruding the comb-tooth-like part of the second liquid-crystal driving electrode toward the comb-tooth-like part of the first liquid-crystal driving electrode.

8. The device according to claim 1, further comprising a common bus line electrically connected to the second liquid-crystal driving electrode;

wherein the common bus line comprises a protruding part formed to protrude toward a top end of the comb-tooth-like part of the second liquid-crystal driving electrode.

9. The device according to claim 1, further comprising a source electrode of a thin-film transistor, which is electrically connected to the first liquid-crystal driving electrode;

wherein the source electrode comprises a protruding part formed to protrude toward a bottom end of the comb-tooth-like part of the first liquid-crystal driving electrode.

10. The device according to claim 1, wherein the region where images are displayed by applying the liquid-crystal driving electric field to the liquid crystal is divided by a dividing line into a first subregion including a thin-film transistor and a second subregion not including a thin-film transistor; and

the first and second subregions are bent to have an approximately V-like shape.

* * * * *

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摘要(译)

当采用使用浮动电极的反向旋转域防止结构时，横向电场型液晶显示装置防止产生反向旋转域。第一液晶驱动电极（例如，像素电极）和第二液晶驱动电极（例如，公共电极）包括分别彼此大致平行并且彼此啮合的梳齿状部分。通过将液晶驱动电场施加到液晶来显示图像的区域。电隔离的第一浮动电极设置在第一液晶驱动电极的梳齿状部分的顶端附近，其中第一浮动电极包括与顶端重叠的重叠部分绝缘膜。介于第一浮动电极和第一液晶驱动电极之间的电容大于介于第一浮动电极和第二液晶驱动电极之间的电容。