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(54) LIQUID CRYSTAL DISPLAY DEVICE

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(57) **ABSTRACT**

A liquid crystal display device includes: first and second substrates facing and spaced apart from each other, the first and second substrates having a pixel region; a gate line and a data line on an inner surface of the first substrate, the gate line and the data line crossing each other adjacent to the pixel region; a thin film transistor connected to the gate line and the data line in the pixel region; a first electrode of a plate shape over the thin film transistor; a second electrode of a bar shape over the first electrode; and a liquid crystal layer between the first and second substrates.

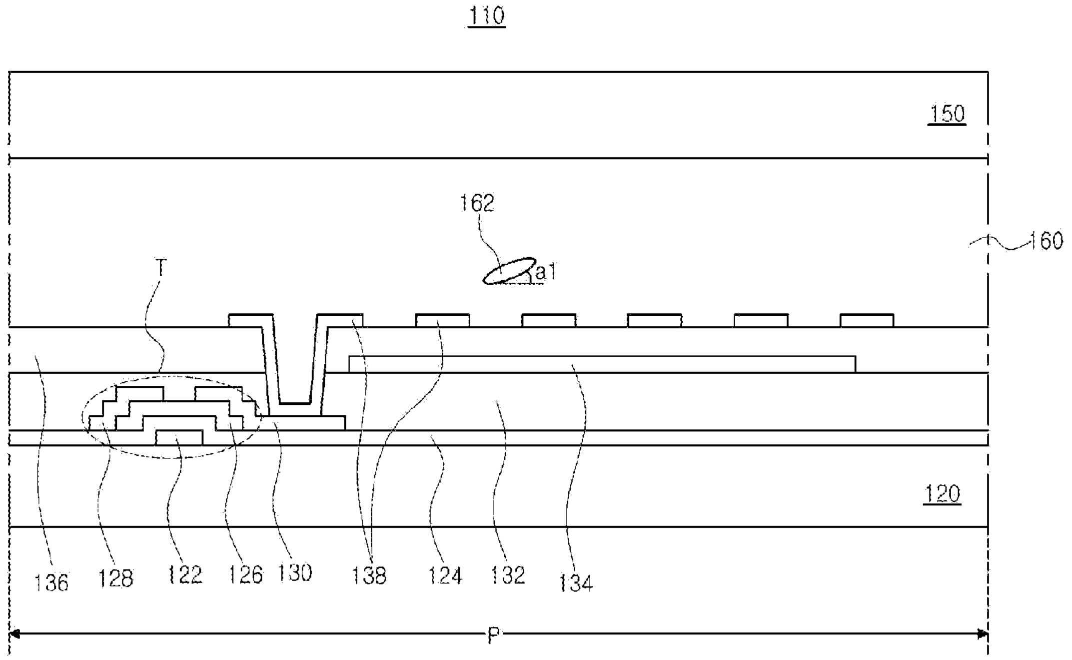


FIG. 1
Related Art

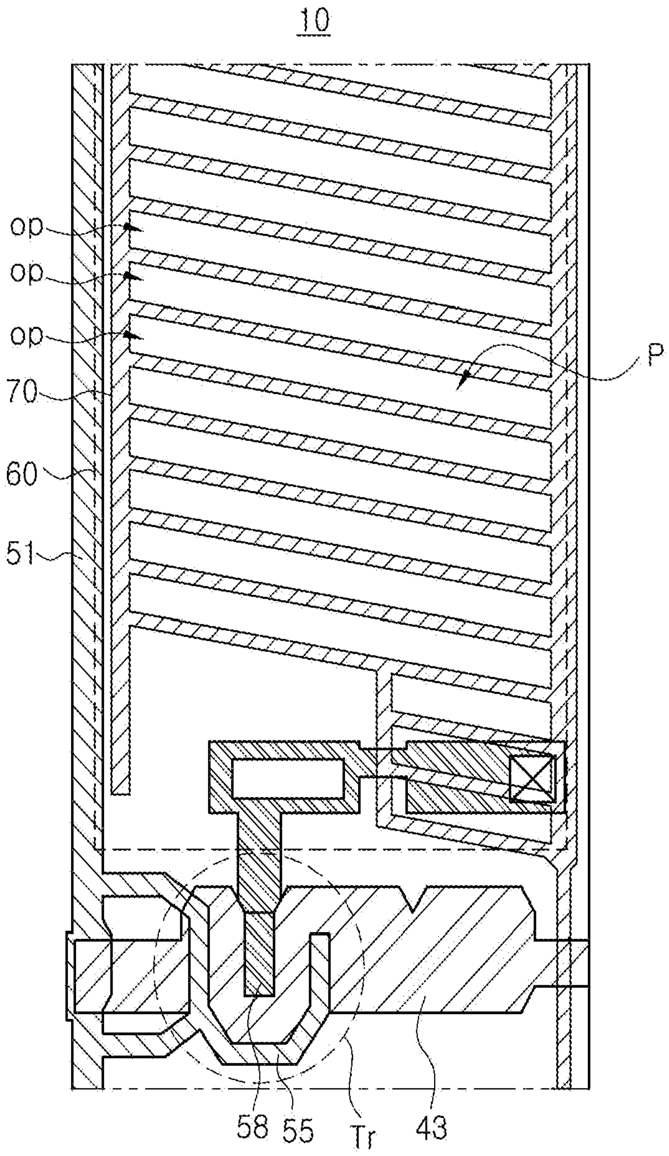


FIG. 2

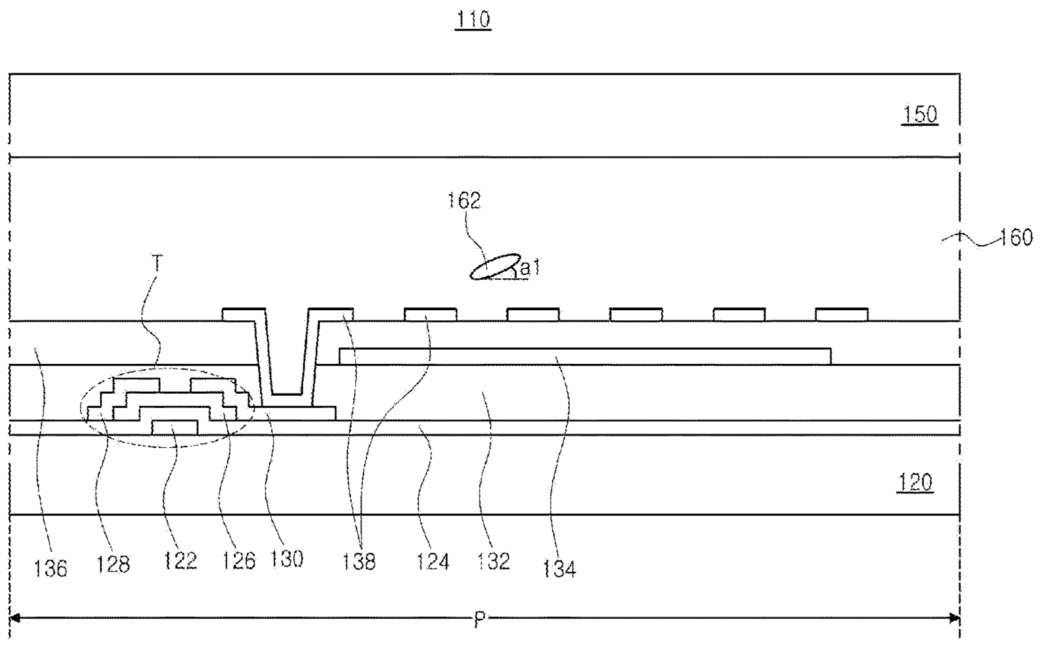


FIG. 3

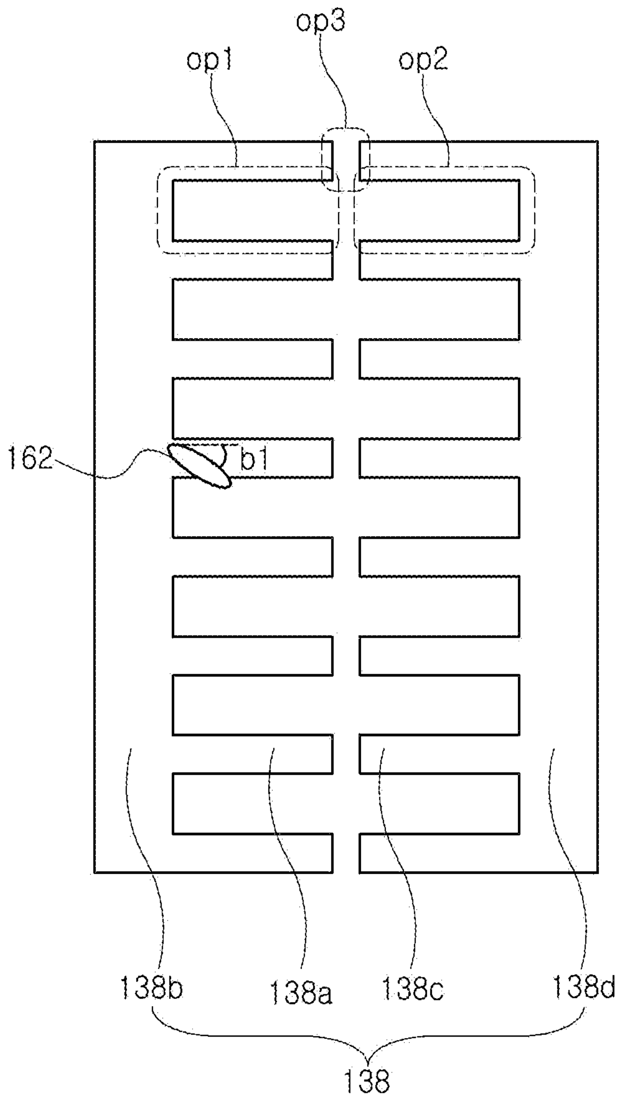


FIG. 4

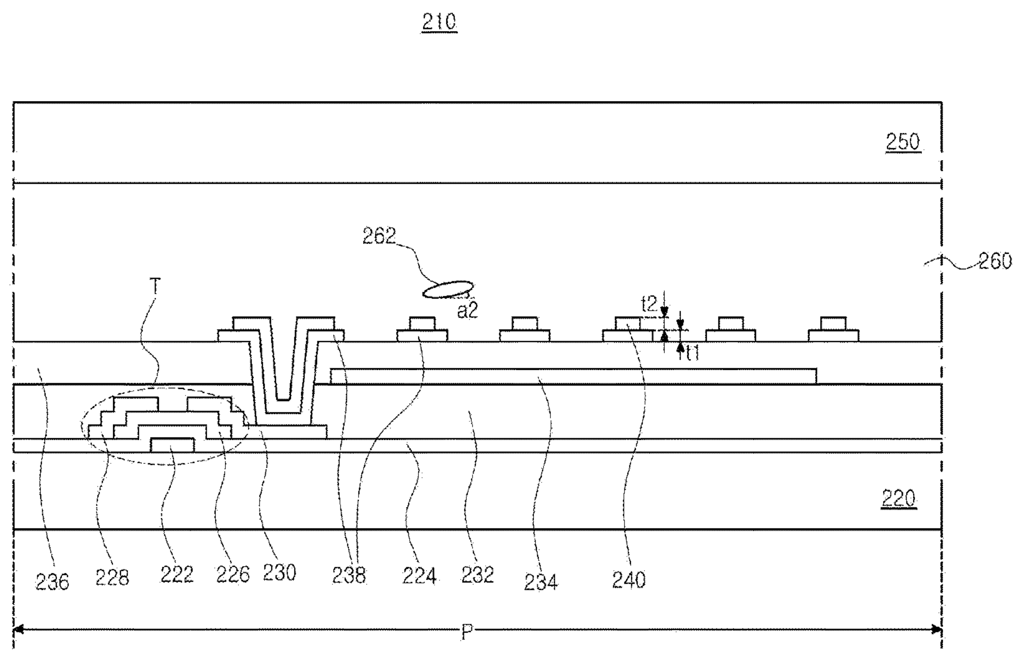

210
250
262
260
T
a2
t2
t1
220
236
228
222
226
230
238
224
232
234
240
P

FIG. 5

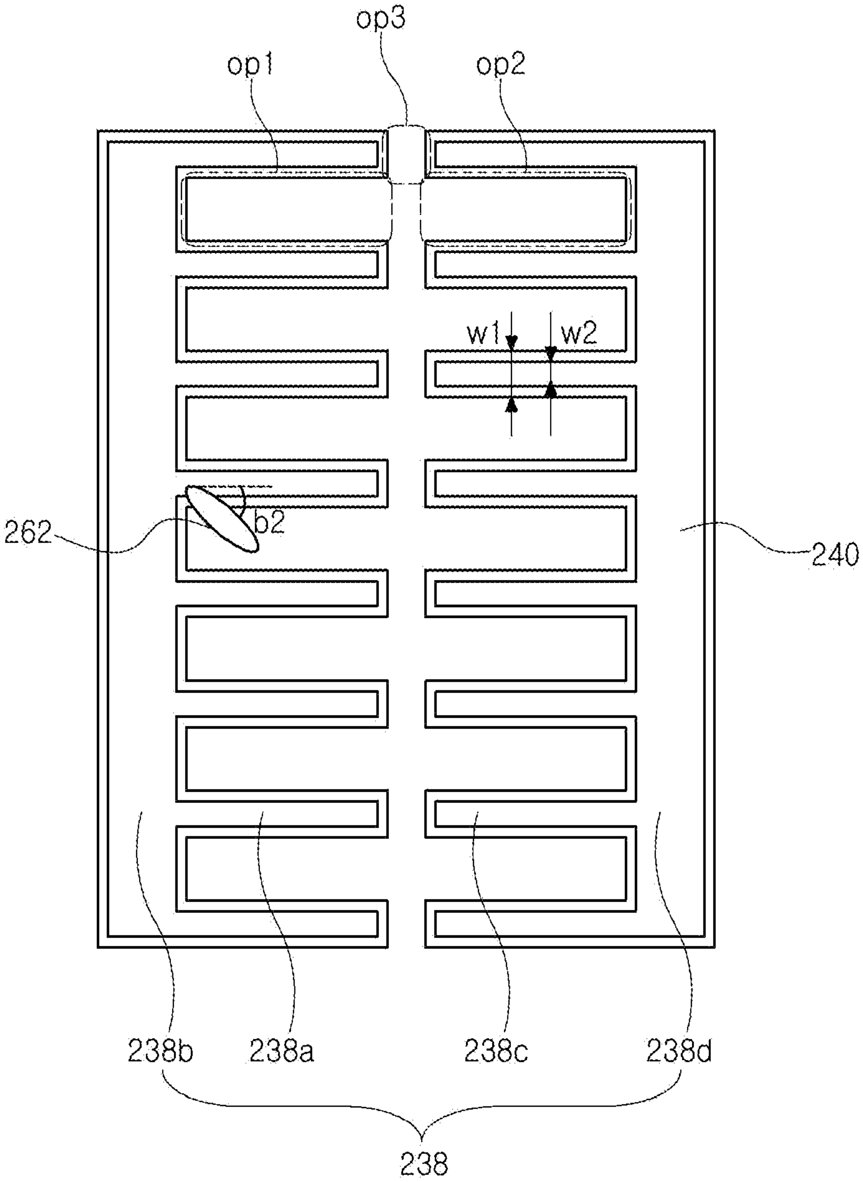


FIG. 6

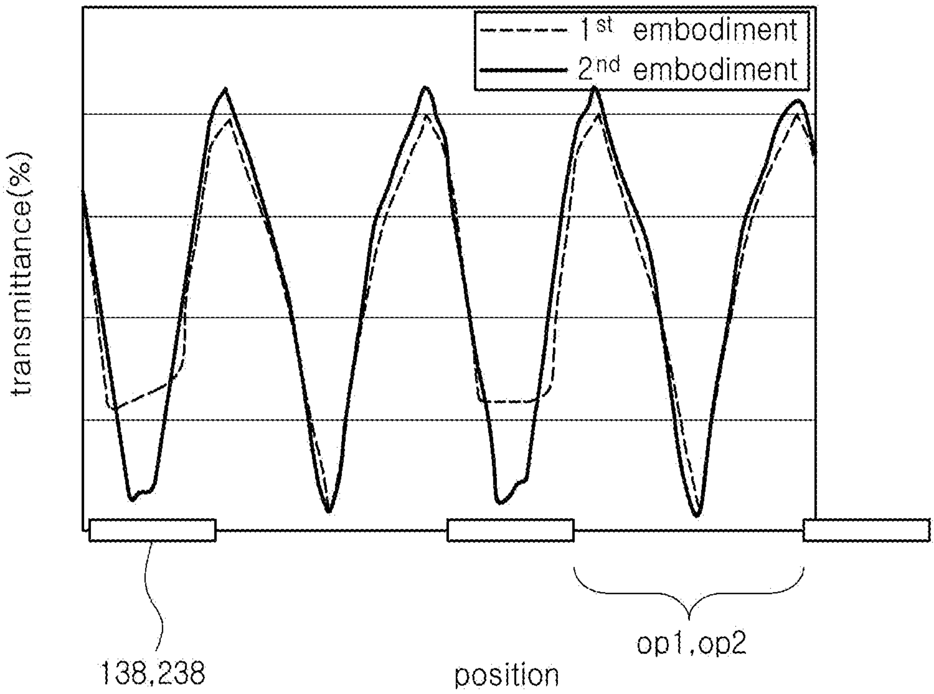

1st embodiment
2nd embodiment
transmittance(%)
138,238
position
op1,op2

FIG. 7

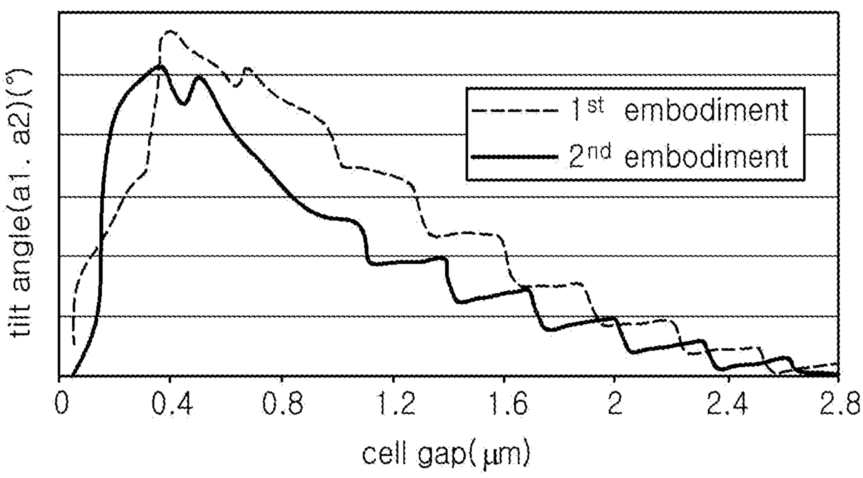

1st embodiment
2nd embodiment
tilt angle(a1. a2)(°)
0
0.4
0.8
1.2
1.6
2
2.4
2.8
cell gap(μm)

FIG. 8

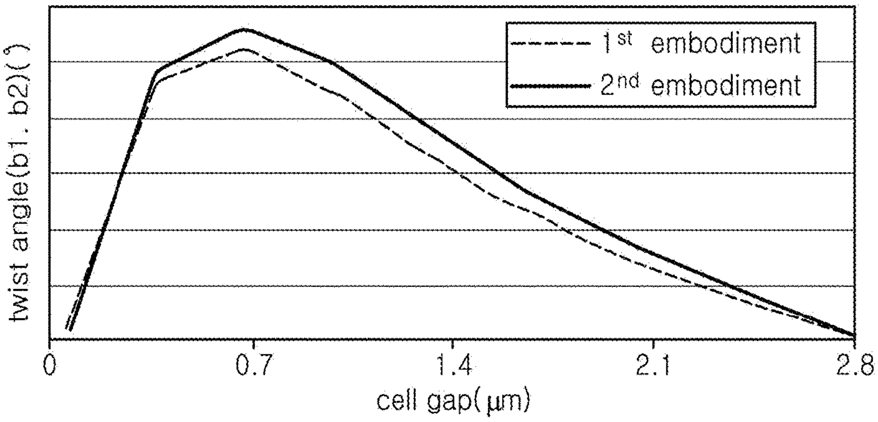

twist angle(b1. b2)(°)
1st embodiment
2nd embodiment
0
0.7
1.4
2.1
2.8
cell gap(μm)

FIG. 9

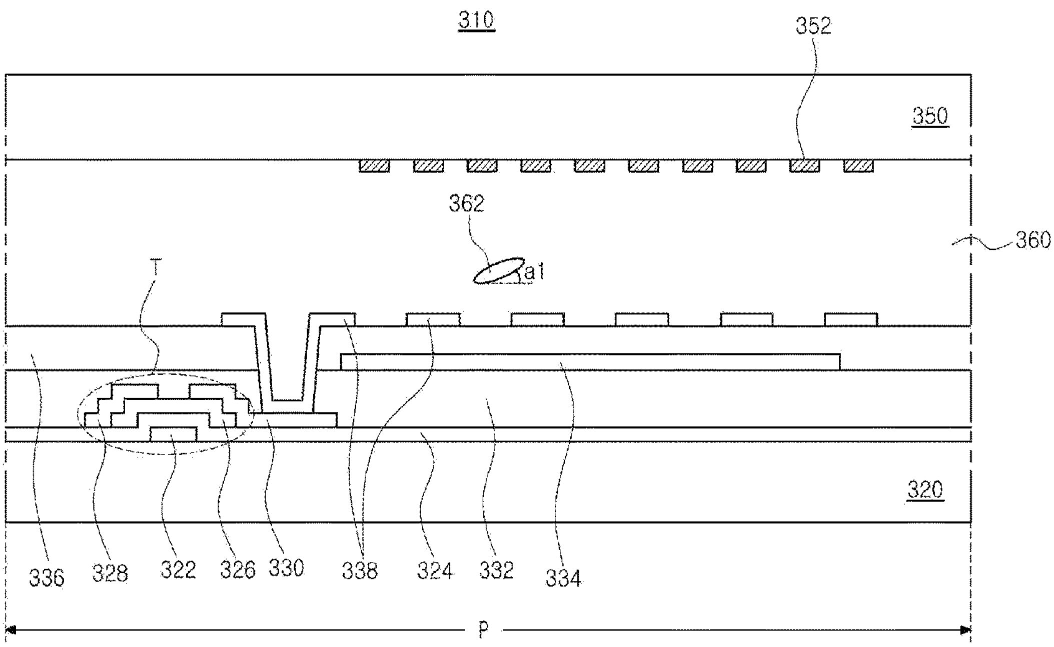

310
352
350
362
360
a1
T
320
336
328
322
326
330
338
324
332
334
P

FIG. 10

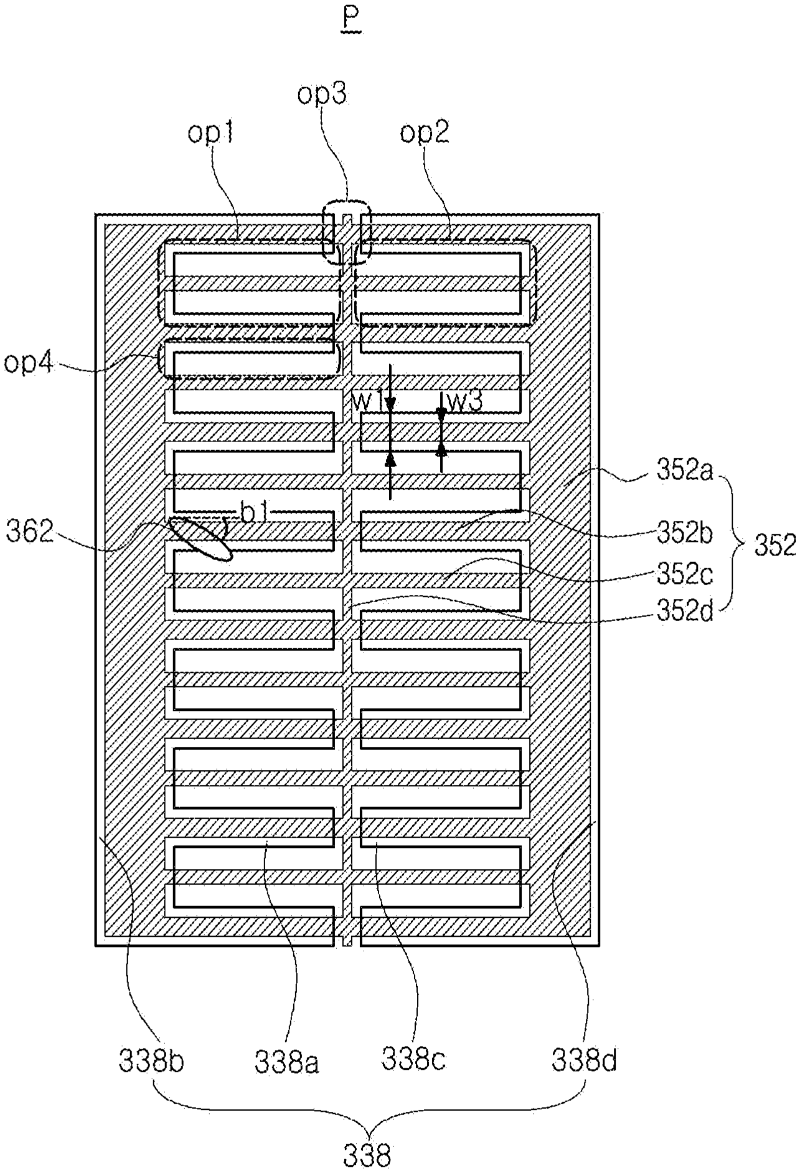

P
op3
op1
op2
op4
w1
w3
352a
352
352b
352c
352d
362
b1
338b
338a
338c
338d
338

FIG. 11

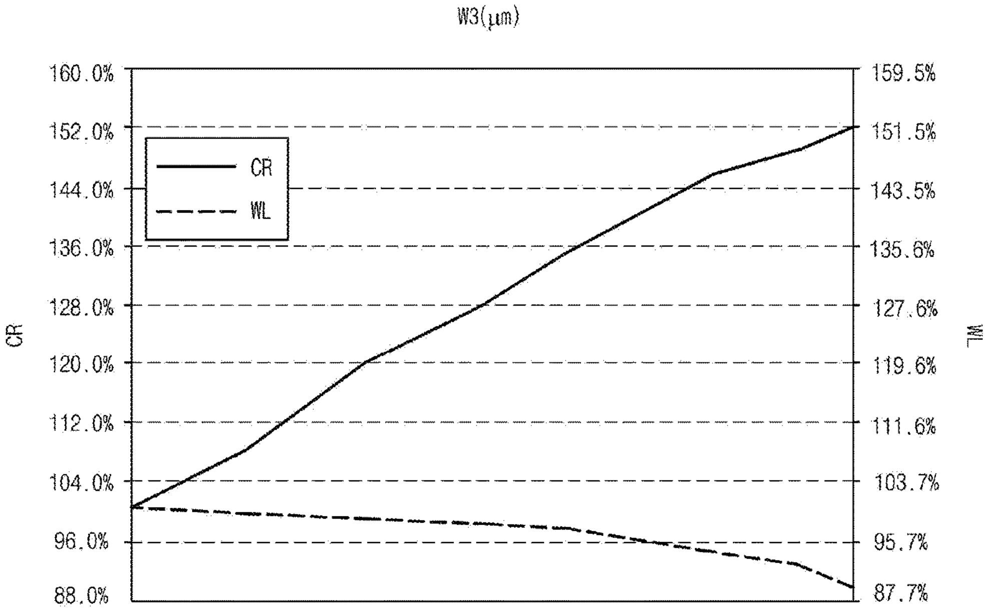


FIG. 12

		CR	WL
1st embodiment	0.0 μm	100.0%	100.0%
3rd embodiment	0.4 μm	108.0%	99.4%
	0.8 μm	119.7%	98.9%
	1.2 μm	127.7%	98.1%
	1.5 μm	134.9%	97.0%
	2.0 μm	145.6%	94.4%
	2.3 μm	149.3%	92.5%
	2.5 μm	152.2%	89.5%

FIG. 13

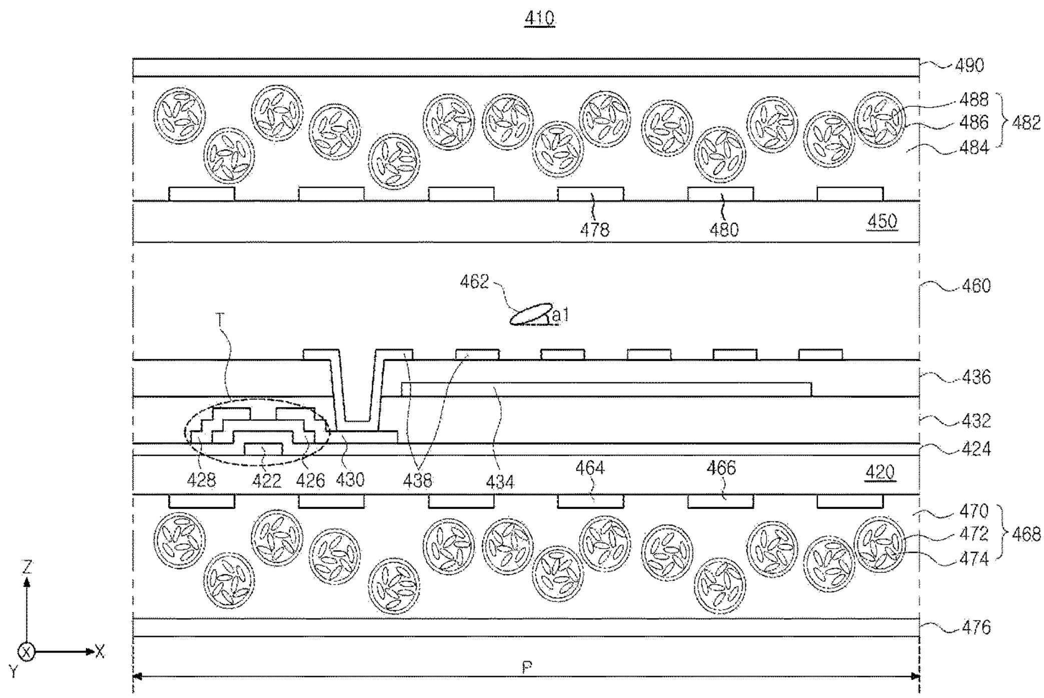

410
490
488
486
482
484
478
480
450
462
a1
460
T
436
432
424
428
422
426
430
438
434
464
466
420
470
472
468
474
476
Z
X
Y
P

FIG. 14

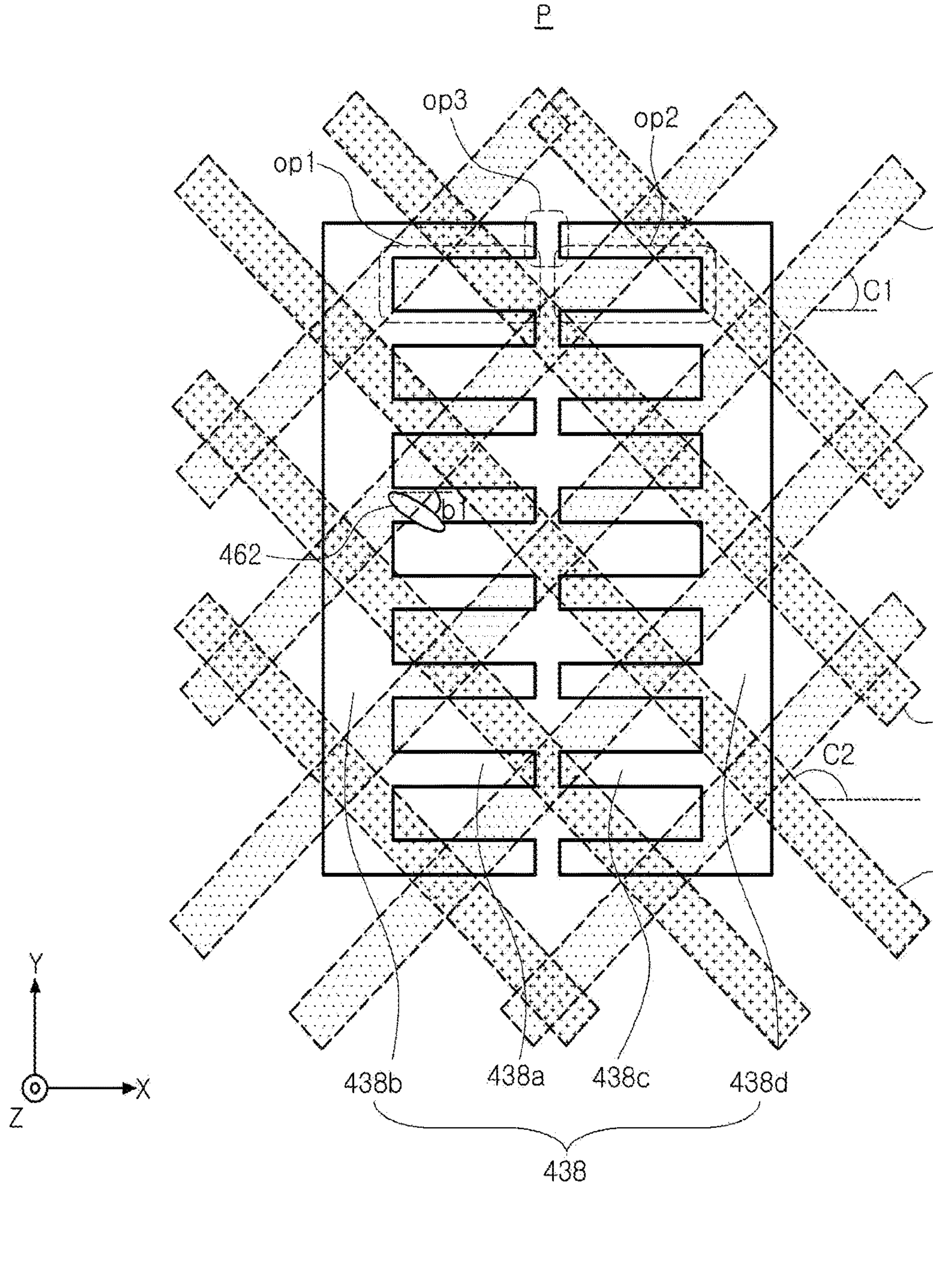

P
op3
op1
op2
466
C1
464
b1
462
C2
478
480
Y
X
Z
438b
438a
438c
438d
438

FIG. 15A

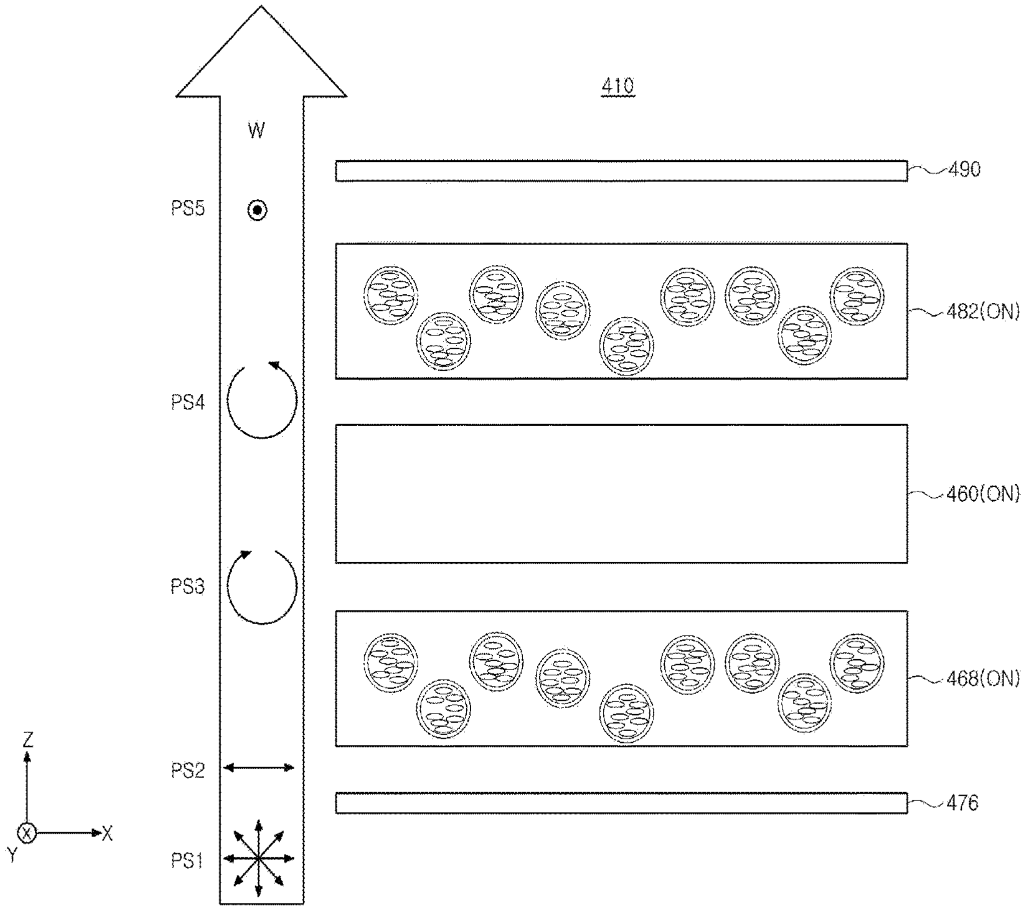
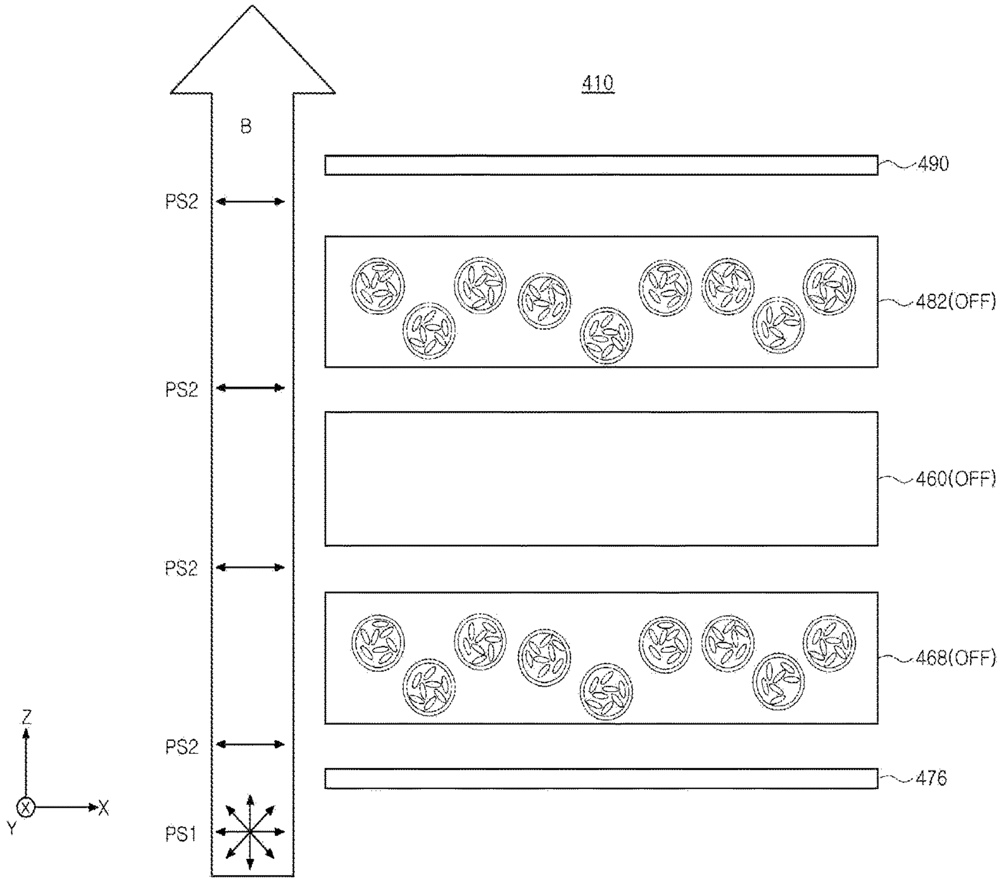


FIG. 15B



LIQUID CRYSTAL DISPLAY DEVICE

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application claims the benefit of priority of Korean Patent Application No. 10-2017-0165218, filed in the Republic of Korea on Dec. 4, 2017, No. 10-2018-0096209, filed in the Republic of Korea on Aug. 17, 2018 and No. 10-2018-0099307, filed in the Republic of Korea on Aug. 24, 2018, which are hereby incorporated by reference in its entirety for all purposes as if fully set forth herein.

BACKGROUND

Technical Field

[0002] The present disclosure relates to a liquid crystal display device, and more particularly, to a liquid crystal display device where a response speed, a transmittance and a white luminance are improved by forming a dielectric pattern on an electrode having a plurality of openings, by forming a black matrix corresponding to an electrode and a plurality of openings or by forming first and second liquid crystal capsule layers on outer surfaces of first and second substrates, respectively.

Description of the Related Art

[0003] In general, a liquid crystal display (LCD) device is driven by using an optical anisotropy and a polarization property of a liquid crystal. Since a liquid crystal molecule has a long and thin structure, an arrangement of the liquid crystal molecule has directionality. As a result, the arrangement direction of the liquid crystal molecule may be adjusted by applying an electric field to the liquid crystal molecule.

[0004] When the arrangement direction of the liquid crystal molecule is adjusted, the arrangement of the liquid crystal molecule is changed and a light is refracted along the arrangement direction of the liquid crystal molecule due to the optical anisotropy to display an image.

[0005] Recently, an active matrix liquid crystal display (AM-LCD) device where a thin film transistor (TFT) and a pixel electrode connected to the TFT are disposed in a matrix has been the subject of research and development due to having superior resolution and excellent display quality for a moving image.

[0006] The LCD device includes a color filter substrate having a common electrode, an array substrate having a pixel electrode and a liquid crystal layer between the color filter substrate and the array substrate. In the LCD device including the color filter substrate and the array substrate, the liquid crystal layer is driven by a vertical electric field between the common electrode and the pixel electrode. The LCD device including the color filter substrate and the array substrate has excellent properties in transmittance and aperture ratio.

[0007] An in-plane switching (IPS) mode LCD device, where a common electrode and a pixel electrode are alternately disposed on one of two substrates and a liquid crystal layer is disposed between two substrates, has been developed.

[0008] The IPS mode LCD device may adjust a light transmittance of the liquid crystal layer having a dielectric anisotropy (ΔΟ) by using a horizontal electric field to display an image.

[0009] In addition, a fringe field switching (FFS) mode LCD device having a viewing angle property superior to the IPS mode LCD device has been suggested.

[0010] FIG. **1** is a plan view showing a fringe field switching mode liquid crystal display device of the related art.

[0011] In FIG. **1**, a fringe field switching (FFS) mode liquid crystal display (LCD) device **10** of the related art includes a gate line **43** of a straight line shape along a direction and a data line **51** of a straight line shape. The gate line **43** and the data line **51** crossing each other are disposed adjacent to a pixel region P.

[0012] A thin film transistor (TFT) Tr connected to the gate line **43** and the data line **51** is disposed in the pixel region P. The TFT Tr includes a gate electrode (not shown), a gate insulating layer (not shown), a semiconductor layer (not shown), a source electrode **55** and a drain electrode **58**.

[0013] A common electrode **60** of a plate shape and a pixel electrode **70** overlapping the common electrode **60** are disposed in the pixel region P. The pixel electrode **70** has a plurality of openings op each having a bar shape. Although the common electrode **60** is formed in a whole display region, the common electrode **60** is shown by a dotted line corresponding to one pixel region P.

[0014] In the FFS mode LCD device **10**, a fringe field is generated by applying a voltage to the pixel electrode **70** having the opening of a shape of a plurality of bar in each pixel region P and the common electrode **60**, and accordingly a liquid crystal layer is driven by the fringe field.

[0015] To increase a reality of a display, a high speed response of an LCD device has been researched. A response time inversely proportional to a response speed may be represented by a time from a bright gray to a dark gray (gray to gray: GTG). For example, the GTG may be measured as a transition time from a luminance of 10% to a luminance of 90%.

[0016] In virtual reality (VR) equipment, due to an electro-optic effect of a liquid crystal of a fluid, the response speed is limited by the motion of the liquid crystal to cause an afterimage such as flickering of an image. In addition, although a viewing angle property is improved in the FFS mode LCD device of the related art, the FFS mode LCD device of the related art has limitations in increasing the response speed.

BRIEF SUMMARY

[0017] Accordingly, embodiments of the present disclosure are directed to a liquid crystal display device that substantially obviates one or more of the problems due to limitations and disadvantages of the related art.

[0018] Aspects of the present disclosure relate to a liquid crystal display device where a response speed, a transmittance and a white luminance are improved.

[0019] Additional features and aspects will be set forth in the description that follows, and in part will be apparent from the description, or may be learned by practice of the inventive concepts provided herein. Other features and aspects of the inventive concepts may be realized and attained by the structure particularly pointed out in the written description, or derivable therefrom, and the claims hereof as well as the appended drawings.

[0020] To achieve these and other aspects of the inventive concepts, as embodied and broadly described, a liquid crystal display device includes: first and second substrates facing and spaced apart from each other, the first and second substrates having a pixel region; a gate line and a data line on an inner surface of the first substrate, the gate line and the data line crossing each other disposed adjacent to the pixel region; a thin film transistor connected to the gate line and the data line in the pixel region; a first electrode of a plate shape over the thin film transistor; a second electrode of a bar shape over the first electrode; and a liquid crystal layer between the first and second substrates, wherein the second electrode includes: a plurality of first bars spaced apart from each other and extending along a first direction parallel to the gate line; a first connecting part connecting the plurality of first bars and extending along a second direction parallel to the data line; a plurality of second bars symmetric to the plurality of first bars with respect to a central line of the pixel region, the plurality of second bars spaced apart from each other and extending along the first direction; and a second connecting part connecting the plurality of second bars and extending along the second direction.

[0021] It is to be understood that both the foregoing general description and the following detailed description are explanatory, and are intended to provide further explanation of the aspects as claimed.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0022] The accompanying drawings, which are included to provide a further understanding of the disclosure, are incorporated in and constitute a part of this application, illustrate embodiments of the disclosure and together with the description serve to explain the principles of the disclosure. In the drawings:

[0023] FIG. **1** is a plan view showing a fringe field switching mode liquid crystal display device of the related art;

[0024] FIG. **2** is a cross-sectional view showing a liquid crystal display device according to a first embodiment of the present disclosure;

[0025] FIG. **3** is a plan view showing a second electrode of a liquid crystal display device according to a first embodiment of the present disclosure;

[0026] FIG. **4** is a cross-sectional view showing a liquid crystal display device according to a second embodiment of the present disclosure;

[0027] FIG. **5** is a plan view showing a second electrode and a dielectric pattern of a liquid crystal display device according to a second embodiment of the present disclosure;

[0028] FIG. **6** is a graph showing a transmittance with respect to a position of a liquid crystal display device according to first and second embodiments of the present disclosure;

[0029] FIG. **7** is a graph showing a tilt angle of a liquid crystal molecule with respect to a cell gap of a liquid crystal display device according to a second embodiment of the present disclosure;

[0030] FIG. **8** is a graph showing a twist angle of a liquid crystal molecule with respect to a cell gap of a liquid crystal display device according to first and second embodiments of the present disclosure;

[0031] FIG. **9** is a cross-sectional view showing a liquid crystal display device according to a third embodiment of the present disclosure;

[0032] FIG. **10** is a plan view showing a second electrode and a black matrix of a liquid crystal display device according to a third embodiment of the present disclosure;

[0033] FIG. **11** is a graph showing a contrast ratio and a white luminance with respect to a width of a black matrix of a liquid crystal display device according to a third embodiment of the present disclosure;

[0034] FIG. **12** is a table illustrating a contrast ratio and a white luminance with respect to a width of a black matrix of a liquid crystal display device according to a third embodiment of the present disclosure;

[0035] FIG. **13** is a cross-sectional view showing a liquid crystal display device according to a fourth embodiment of the present disclosure;

[0036] FIG. **14** is a plan view showing a second electrode, first and second capsule electrodes and third and fourth capsule electrodes of a liquid crystal display device according to a fourth embodiment of the present disclosure; and

[0037] FIGS. **15**A and **15**B are cross-sectional views showing a polarization state of an ON state and an OFF state, respectively, of a liquid crystal display device according to a fourth embodiment of the present disclosure.

DETAILED DESCRIPTION

[0038] Reference will now be made in detail to aspects of the present disclosure, examples of which are illustrated in the accompanying drawings. In the following description, when a detailed description of well-known functions or configurations related to this document is determined to unnecessarily cloud a gist of an aspect of the disclosure, the detailed description thereof will be omitted. The progression of processing steps and/or operations described is an example; however, the sequence of steps and/or operations is not limited to that set forth herein and may be changed as is known in the art, with the exception of steps and/or operations necessarily occurring in a certain order. Like reference numerals designate like elements throughout. Names of the respective elements used in the following explanations are selected only for convenience of writing the specification and may be thus different from those used in actual products.

[0039] FIG. **2** is a cross-sectional view showing a liquid crystal display device according to a first embodiment of the present disclosure, and FIG. **3** is a plan view showing a second electrode of a liquid crystal display device according to a first embodiment of the present disclosure.

[0040] In FIGS. **2** and **3**, a liquid crystal display (LCD) device **110** according to a first embodiment of the present disclosure includes first and second substrates **120** and **150** facing and spaced apart from each other and a liquid crystal layer **160** between the first and second substrates **120** and **150**. The first and second substrates **120** and **150** include a plurality of pixel regions P.

[0041] A thin film transistor (TFT) T and first and second electrodes **134** and **138** are disposed in each of the plurality of pixel regions P on an inner surface of the first substrate **120**. A gate electrode **122** is disposed in each of the plurality of pixel regions P on the inner surface of the first substrate **120**, and a gate insulating layer **124** is disposed on the gate electrode **122** in a whole of the first substrate **120**.

[0042] A semiconductor layer **126** is disposed on the gate insulating layer **124** corresponding to the gate electrode **122**, and a source electrode **128** and a drain electrode **130** spaced apart from each other are disposed on both end portions of the semiconductor layer **126**.

[0043] The gate electrode **122**, the semiconductor layer **126**, the source electrode **128** and the drain electrode **130** constitute the TFT T.

[0044] Although not shown, a gate line and a data line are disposed over the first substrate **120** and the TFT T is connected to the gate line and the data line. The gate line and the data line crossing each other to form the pixel region P adjacent to the crossing location.

[0045] A first insulating layer **132** is disposed on the TFT T in a whole of the first substrate **120**, and a first electrode **134** of a plate shape is disposed on the first insulating layer **132** in each pixel region P.

[0046] A second insulating layer **136** is disposed on the first electrode **134** in a whole of the first substrate **120**, and a second electrode **138** of a bar shape is disposed on the second insulating layer **136** corresponding to the first electrode **134**.

[0047] The second electrode **138** is connected to the drain electrode **130** of the TFT T through a drain contact hole of the first and second insulating layers **132** and **136**. The second electrode **138** may include a plurality of first bars **138***a*, a first connecting part **138***b*, a plurality of second bars **138***c* and a second connecting part **138***d*. The plurality of first bars **138***a* are extended along a first direction parallel to the gate line. The first connecting part **138***b* connects the plurality of first bars **138***a* and is extended along a second direction parallel to the data line. The plurality of second bars **138***c* are symmetric to the plurality of first bars **138***a* with respect to a central line of the pixel region P and are extended along the first direction. The second connecting part **138***d* connects the plurality of second bars **138***c* and is extended along the second direction.

[0048] The second electrode **138** has a first opening op**1** between the plurality of first bars **138***a*, a second opening op**2** between the plurality of second bars **138***c* and a third opening op**3** between the plurality of first bars **138***a* and the plurality of second bars **138***c*.

[0049] For example, a length of a side along the second direction of the first and second openings op**1** and op**2**, which is a gap distance between adjacent two of the plurality of first bars **138***a* and is a gap distance between adjacent two of the plurality of second bars **138***c*, may be about 1 μm to about 5 μm.

[0050] A length of a side along the first direction of the third opening op**3**, which is a gap distance between the plurality of first bars **138***a* and the plurality of second bars **138***c*, may be about 3% to about 15% of a length of a side along the first direction of the pixel region P and may be about 5% to about 20% of a length of a side along the first direction of the second electrode **138**. For example, the length of a side along the first direction of the third opening op**3** may be about 1 μm to about 5 μm.

[0051] Although the first electrode **134** is a common electrode and the second electrode **138** is a pixel electrode connected to the TFT T in the first embodiment, the first electrode **134** may be a pixel electrode connected to the TFT T and the second electrode **138** may be a common electrode in another embodiment.

[0052] The liquid crystal layer **160** includes a plurality of liquid crystal molecules **162**. The liquid crystal molecule **162** on an edge portion of the plurality of first bars **138***a* and the plurality of second bars **138***c* of the second electrode **138** may have a first tilt angle a**1** with respect to the first substrate **120** and have a first twist angle b**1** with respect to the first direction after an electric field is generated.

[0053] The liquid crystal layer **160** may be initially aligned along the first direction and the plurality of liquid crystal molecules **162** may have a positive dielectric anisotropy ($\Delta\varepsilon>0$). Alternatively, the liquid crystal layer **160** may be initially aligned along the second direction and the plurality of liquid crystal molecules **162** may have a negative dielectric anisotropy ($\Delta\varepsilon<0$).

[0054] In the LCD device **110**, a voltage is applied to the first and second electrodes **134** and **138** to generate an electric field. An electric field along the second direction may be generated at a side extending along the first direction of the plurality of first bars **138***a* and the plurality of second bars **138***c*, and an electric field along the first direction may be generated at a side extending along the second direction of the plurality of first bars **138***a* and the plurality of second bars **138***c* and a side extending along the second direction of the first and second connecting parts **138***b* and **138***d*. An electric field along a diagonal direction between the first and second directions may be generated at a corner portion of the first, second and third openings op**1**, op**2** and op**3**.

[0055] The liquid crystal molecule **162** at the corner portion of the first, second and third openings op**1**, op**2** and op**3**, which is disposed along the first direction before the voltage is applied, rotates in preference to a clockwise direction or a counterclockwise direction by the electric field along the diagonal direction to be promptly realigned after the voltage is applied.

[0056] The liquid crystal molecule **162** at the side extending along the first direction of the plurality of first bars **138***a* and the plurality of second bars **138***c*, which is extended along the first direction before the voltage is applied, rotates without preference to a clockwise direction or a counterclockwise direction by the electric field along the second direction to be realigned after the voltage is applied. The liquid crystal molecule **162** at the side extending along the first direction of the plurality of first bars **138***a* and the plurality of second bars **138***c* is promptly realigned due to the realigned liquid crystal molecule **162** at the corner portion of the first, second and third openings op**1**, op**2** and op**3**.

[0057] Accordingly, in the LCD device **110** according to the first embodiment, the liquid crystal layer **160** is driven by the electric field generated between the first and second electrodes **134** and **138**. The liquid crystal molecule **162** at the corner portion of the first, second and third openings op**1**, op**2** and op**3** is promptly realigned in preference to a rotational direction, and the liquid crystal molecule **162** at the side extending along the first direction of the plurality of first bars **138***a* and the plurality of second bars **138***c* is promptly realigned due to the realignment of the liquid crystal molecule **162** at the corner portion of the first, second and third openings op**1**, op**2** and op**3**. As a result, a response time defined as a sum of a rising time and a falling time of the liquid crystal molecule **162** is reduced and a response speed increases. Therefore, the LCD device **110** may be easily applied to virtual reality (VR) equipment.

[0058] For example, the rising time, the falling time and the response time of the liquid crystal molecule **162** may be about 7.7 msec, about 2.6 msec and about 10.3 msec, respectively.

[0059] In the LCD device **110**, a disclination corresponding to a central portion of the plurality of first bars **138***a* and the plurality of second bars **138***c* of the second electrode **138** and a central portion of the first, second and third openings op**1**, op**2** and op**3** may be generated. As a result, transmittance, brightness and contrast ratio of the LCD device **110** may be reduced.

[0060] To improve reduction of the transmittance and the brightness, a dielectric pattern may be formed on the second electrode **138** in another embodiment.

[0061] FIG. **4** is a cross-sectional view showing a liquid crystal display device according to a second embodiment of the present disclosure, and FIG. **5** is a plan view showing a second electrode and a dielectric pattern of a liquid crystal display device according to a second embodiment of the present disclosure. Illustration of parts the same as the first embodiment may be omitted.

[0062] In FIGS. **4** and **5**, a liquid crystal display (LCD) device **210** according to a second embodiment of the present disclosure includes first and second substrates **220** and **250** facing and spaced apart from each other and a liquid crystal layer **260** between the first and second substrates **220** and **250**. The first and second substrates **220** and **250** include a plurality of pixel regions P.

[0063] A thin film transistor (TFT) T and first and second electrodes **234** and **238** are disposed in each of the plurality of pixel regions P on an inner surface of the first substrate **220**. A gate electrode **222** is disposed in each of the plurality of pixel regions P on the inner surface of the first substrate **220**, and a gate insulating layer **224** is disposed on the gate electrode **222** in a whole of the first substrate **220**.

[0064] A semiconductor layer **226** is disposed on the gate insulating layer **224** corresponding to the gate electrode **222**, and a source electrode **228** and a drain electrode **230** spaced apart from each other are disposed on both end portions of the semiconductor layer **226**.

[0065] The gate electrode **222**, the semiconductor layer **226**, the source electrode **228** and the drain electrode **230** constitute the TFT T.

[0066] Although not shown, a gate line and a data line are disposed over the first substrate **220** and the TFT T is connected to the gate line and the data line. The gate line and the data line cross each other adjacent to the pixel region P.

[0067] A first insulating layer **232** is disposed on the TFT T in a whole of the first substrate **220**, and a first electrode **234** of a plate shape is disposed on the first insulating layer **232** in each pixel region P.

[0068] A second insulating layer **236** is disposed on the first electrode **234** in a whole of the first substrate **220**, and a second electrode **238** of a bar shape is disposed on the second insulating layer **236** corresponding to the first electrode **234**.

[0069] The second electrode **238** is connected to the drain electrode **230** of the TFT T through a drain contact hole of the first and second insulating layers **232** and **236**. The second electrode **238** may include a plurality of first bars **238***a*, a first connecting part **238***b*, a plurality of second bars **238***c* and a second connecting part **238***d*. The plurality of first bars **238***a* are extended along a first direction parallel to the gate line. The first connecting part **238***b* connects the plurality of first bars **238***a* and is extended along a second direction parallel to the data line. The plurality of second bars **238***c* are symmetric to the plurality of first bars **238***a* with respect to a central line of the pixel region P and are extended along the first direction. The second connecting part **238***d* connects the plurality of second bars **238***c* and is extended along the second direction.

[0070] The second electrode **238** has a first opening op**1** between the plurality of first bars **238***a*, a second opening op**2** between the plurality of second bars **238***c* and a third opening op**3** between the plurality of first bars **238***a* and the plurality of second bars **238***c*.

[0071] For example, a length of a side extending along the second direction of the first and second openings op**1** and op**2**, which is a gap distance between adjacent two of the plurality of first bars **238***a* and is a gap distance between adjacent two of the plurality of second bars **238***c*, may be about 1 μm to about 5 μm.

[0072] A length of a side along the first direction of the third opening op**3**, which is a gap distance between the plurality of first bars **238***a* and the plurality of second bars **238***c*, may be about 3% to about 15% of a length of a side along the first direction of the pixel region P and may be about 5% to about 20% of a length of a side along the first direction of the second electrode **238**. For example, the length of a side along the first direction of the third opening op**3** may be about 1 μm to about 5 μm.

[0073] Although the first electrode **234** is a common electrode and the second electrode **238** is a pixel electrode connected to the TFT T in the second embodiment, the first electrode **234** may be a pixel electrode connected to the TFT T and the second electrode **238** may be a common electrode in another embodiment.

[0074] A dielectric pattern **240** having the same shape as the second electrode **238** is disposed on the second electrode **238**. For example, the dielectric pattern **240** may include an inorganic insulating material such as silicon oxide (SiO_2) and silicon nitride (SiNx) or an organic insulating material such as photoacryl and benzocyclobutene (BCB).

[0075] The second electrode **238** and the dielectric pattern **240** have first and second thicknesses t**1** and t**2**, respectively. For example, the first and second thicknesses t**1** and t**2** may be the same as each other.

[0076] The dielectric pattern **240** on each of the plurality of first bars **238***a* and the plurality of second bars **238***c* may have a second width w**2** substantially the same as a width of a disclination on each of the plurality of first bars **238***a* and the plurality of second bars **238***c*.

[0077] For example, when each of the plurality of first bars **238***a* and the plurality of second bars **238***c* of the second electrode **238** has a first width w**1**, the second width w**2** of the dielectric pattern **240** on each of the plurality of first bars **238***a* and the plurality of second bars **238***c* may be within a range of about 25% to about 50% of the first width w**1**.

[0078] The liquid crystal layer **260** includes a plurality of liquid crystal molecules **262**. The liquid crystal molecule **262** on an edge portion of the plurality of first bars **238***a* and the plurality of second bars **238***c* of the second electrode **238** may have a second tilt angle a**2** with respect to the first substrate **220** and have a second twist angle b**2** with respect to the first direction after an electric field is generated. Since the electric field is modified by the dielectric pattern **240**, the second tilt angle a**2** of the second embodiment may be smaller than the first tilt angle a**1** of the first embodiment (a2<a1) and the second twist angle **b2** of the second embodiment may be greater than the first twist angle **b1** of the first embodiment (b2>b1).

[0079] For example, the second tilt angle a**2** may be smaller than the first tilt angle a**1** by about 0.6 degrees (a2−a1=−0.6°), and the second twist angle b**2** may be greater than the first twist angle b**1** by about 45 degrees (b2−b1=+45°).

[0080] The liquid crystal layer **260** may be initially aligned along the first direction and the plurality of liquid crystal molecules **262** may have a positive dielectric anisotropy ($\Delta\varepsilon>0$). Alternatively, the liquid crystal layer **260** may be initially aligned along the second direction and the plurality of liquid crystal molecules **262** may have a negative dielectric anisotropy ($\Delta\varepsilon<0$).

[0081] In the LCD device **210**, a voltage is applied to the first and second electrodes **234** and **238** to generate an electric field. An electric field along the second direction may be generated at a side extending along the first direction of the plurality of first bars **238***a* and the plurality of second bars **238***c*, and an electric field along the first direction may be generated at a side extending along the second direction of the plurality of first bars **238***a* and the plurality of second bars **238***c* and a side extending along the second direction of the first and second connecting parts **238***b* and **238***d*. An electric field along a diagonal direction between the first and second directions may be generated at a corner portion of the first, second and third openings op**1**, op**2** and op**3**.

[0082] The liquid crystal molecule **262** at the corner portion of the first, second and third openings op**1**, op**2** and op**3**, which is disposed along the first direction before the voltage is applied, rotates in preference to a clockwise direction or a counterclockwise direction by the electric field along the diagonal direction to be promptly realigned after the voltage is applied.

[0083] The liquid crystal molecule **262** at the side extending along the first direction of the plurality of first bars **238***a* and the plurality of second bars **238***c*, which is extended along the first direction before the voltage is applied, rotates without preference to a clockwise direction or a counterclockwise direction by the electric field along the second direction to be realigned after the voltage is applied. The liquid crystal molecule **262** at the side extending along the first direction of the plurality of first bars **238***a* and the plurality of second bars **238***c* is promptly realigned due to the realigned liquid crystal molecule **262** at the corner portion of the first, second and third openings op**1**, op**2** and op**3**.

[0084] Accordingly, in the LCD device **210** according to the second embodiment, the liquid crystal layer **260** is driven by the electric field generated between the first and second electrodes **234** and **238**. The liquid crystal molecule **262** at the corner portion of the first, second and third openings op**1**, op**2** and op**3** is promptly realigned in preference to a rotational direction, and the liquid crystal molecule **262** at the side extending along the first direction of the plurality of first bars **238***a* and the plurality of second bars **238***c* is promptly realigned due to the realignment of the liquid crystal molecule **262** at the corner portion of the first, second and third openings op**1**, op**2** and op**3**. As a result, a response time defined as a sum of a rising time and a falling time of the liquid crystal molecule **262** is reduced and a response speed increases. Therefore, the LCD device **210** may be easily applied to virtual reality (VR) equipment.

[0085] For example, the rising time, the falling time and the response time of the liquid crystal molecule **262** may be about 7.53 msec, about 2.72 msec and about 10.25 msec, respectively.

[0086] In addition, since the second tilt angle a**2** of the liquid crystal molecule **262** is reduced and the second twist angle b**2** of the liquid crystal molecule **262** increases as compared with the related art LCD device due to the dielectric pattern **240** disposed on and protruding from the second electrode **238**, the transmittance and the brightness increase.

[0087] FIG. **6** is a graph showing a transmittance with respect to a position of a liquid crystal display device according to first and second embodiments of the present disclosure, FIG. **7** is a graph showing a tilt angle of a liquid crystal molecule with respect to a cell gap of a liquid crystal display device according to first and second embodiments of the present disclosure, and FIG. **8** is a graph showing a twist angle of a liquid crystal molecule with respect to a cell gap of a liquid crystal display device according to first and second embodiments of the present disclosure. Reference is made to FIGS. **2** to **5** with FIGS. **6** to **8**.

[0088] In FIG. **6**, the LCD device **110** and **210** according to the first and second embodiments of the present disclosure may have a relatively low transmittance at a central portion of the plurality of first bars **138***a* and **238***a* and the plurality of second bars **138***c* and **238***c* of the second electrode **138** and **238** and a central portion of the first and second openings op**1** and op**2** and may have a relatively high transmittance at an edge portion of the plurality of first bars **138***a* and **238***a* and the plurality of second bars **138***c* and **238***c* of the second electrode **138** and **238**.

[0089] The transmittance at the edge portion of the plurality of first bars **238***a* and the plurality of second bars **238***c* of the second electrode **238** of the LCD device **210** according to the second embodiment may be greater than the transmittance at the edge portion of the plurality of first bars **138***a* and the plurality of second bars **138***c* of the second electrode **138** of the LCD device **110** according to the first embodiment.

[0090] For example, at the edge portion of the plurality of first bars **138***a* and **238***a* and the plurality of second bars **138***c* and **238***c* of the second electrode **138** and **238**, the transmittance of the LCD device **210** according to the second embodiment may be greater than the transmittance of the LCD device **110** according to the first embodiment by about 6%.

[0091] In FIGS. **7** and **8**, the first and second tilt angles a**1** and a**2** and the first and second twist angles b**1** and b**2** of the LCD device **110** and **210** according to the first and second embodiments of the present disclosure increase and then decrease according to a cell gap. The second tilt angle a**2** of the LCD device **210** according to the second embodiment may be smaller than the first tilt angle a**1** of the LCD device **110** according to the first embodiment, and the second twist angle b**2** of the LCD device **210** according to the second embodiment may be greater than the first twist angle b**1** of the LCD device **110** according to the first embodiment.

[0092] As a result, the transmittance at the edge portion of the plurality of first bars **238***a* and the plurality of second bars **238***c* of the second electrode **238** of the LCD device **210** according to the second embodiment may be greater than the transmittance at the edge portion of the plurality of first bars

138*a* and the plurality of second bars **138***c* of the second electrode **138** of the LCD device **110** according to the first embodiment.

[0093] In the LCD device **210** according to the second embodiment of the present disclosure, since the liquid crystal layer **260** is driven by using the first electrode **234** having a plate shape and the second electrode **238** including the plurality first bars **238***a* and the plurality of second bars **238***c*, a response time defined as a sum of a rising time and a falling time of the liquid crystal molecule **262** is reduced and a response speed increases. Therefore, the LCD device **210** may be easily applied to virtual reality (VR) equipment.

[0094] Further, since the tilt angle of the liquid crystal molecule **262** is reduced and the twist angle of the liquid crystal molecule **262** increases due to the dielectric pattern **240** disposed on and protruding from the second electrode **238**, the transmittance and the brightness of the LCD device **210** are improved.

[0095] In another embodiment, to improve reduction of the contrast ratio due to the disclination of the LCD device **110** of the first embodiment, a black matrix may be formed to correspond to the second electrode **138** and the first, second and third openings op**1**, op**2** and op**3**.

[0096] FIG. **9** is a cross-sectional view showing a liquid crystal display device according to a third embodiment of the present disclosure, and FIG. **10** is a plan view showing a second electrode and a black matrix of a liquid crystal display device according to a third embodiment of the present disclosure. Illustration of parts the same as the first embodiment may be omitted.

[0097] In FIGS. **9** and **10**, a liquid crystal display (LCD) device **310** according to a third embodiment of the present disclosure includes first and second substrates **320** and **350** facing and spaced apart from each other and a liquid crystal layer **360** between the first and second substrates **320** and **350**. The first and second substrates **320** and **350** include a plurality of pixel regions P.

[0098] A thin film transistor (TFT) T and first and second electrodes **334** and **338** are disposed in each of the plurality of pixel regions P on an inner surface of the first substrate **320**. A gate electrode **322** is disposed in each of the plurality of pixel regions P on the inner surface of the first substrate **320**, and a gate insulating layer **324** is disposed on the gate electrode **322** in a whole of the first substrate **320**.

[0099] A semiconductor layer **326** is disposed on the gate insulating layer **324** corresponding to the gate electrode **322**, and a source electrode **328** and a drain electrode **330** spaced apart from each other are disposed on both end portions of the semiconductor layer **326**.

[0100] The gate electrode **322**, the semiconductor layer **326**, the source electrode **328** and the drain electrode **330** constitute the TFT T.

[0101] Although not shown, a gate line and a data line are disposed over the first substrate **320** and the TFT T is connected to the gate line and the data line. The gate line and the data line crossing each other adjacent to the pixel region P.

[0102] A first insulating layer **332** is disposed on the TFT T in a whole of the first substrate **320**, and a first electrode **334** of a plate shape is disposed on the first insulating layer **332** in each pixel region P.

[0103] A second insulating layer **336** is disposed on the first electrode **334** in a whole of the first substrate **320**, and a second electrode **338** of a bar shape is disposed on the second insulating layer **336** corresponding to the first electrode **334**.

[0104] The second electrode **338** is connected to the drain electrode **330** of the TFT T through a drain contact hole of the first and second insulating layers **332** and **336**. The second electrode **338** may include a plurality of first bars **338***a*, a first connecting part **338***b*, a plurality of second bars **338***c* and a second connecting part **338***d*. The plurality of first bars **338***a* are extended along a first direction parallel to the gate line. The first connecting part **338***b* connects the plurality of first bars **338***a* and is extended along a second direction parallel to the data line. The plurality of second bars **338***c* are symmetric to the plurality of first bars **338***a* with respect to a central line of the pixel region P and are extended along the first direction. The second connecting part **338***d* connects the plurality of second bars **338***c* and is extended along the second direction.

[0105] The second electrode **338** has a first opening op**1** between the plurality of first bars **338***a*, a second opening op**2** between the plurality of second bars **338***c* and a third opening op**3** between the plurality of first bars **338***a* and the plurality of second bars **338***c*.

[0106] For example, a length of a side extending along the second direction of the first and second openings op**1** and op**2**, which is a gap distance between adjacent two of the plurality of first bars **338***a* and is a gap distance between adjacent two of the plurality of second bars **338***c*, may be about 1 μm to about 5 μm.

[0107] A length of a side along the first direction of the third opening op**3**, which is a gap distance between the plurality of first bars **338***a* and the plurality of second bars **338***c*, may be about 3% to about 15% of a length of a side along the first direction of the pixel region P and may be about 5% to about 20% of a length of a side along the first direction of the second electrode **338**. For example, the length of a side along the first direction of the third opening op**3** may be about 1 μm to about 5 μm.

[0108] Although the first electrode **334** is a common electrode and the second electrode **338** is a pixel electrode connected to the TFT T in the third embodiment, the first electrode **334** may be a pixel electrode connected to the TFT T and the second electrode **338** may be a common electrode in another embodiment.

[0109] A black matrix **352** corresponding to the second electrode **338** and the first, second and third openings op**1**, op**2** and op**3** is disposed on an inner surface of the second substrate **350**.

[0110] The black matrix **352** covers non-emissive elements such as the gate line, the data line and the TFT T. In addition, the black matrix **352** covers a disclination in the pixel region P to reduce the brightness of the black image and thereby increases the contrast ratio.

[0111] A vertical electric field is generated at a central portion of the plurality of first bars **338***a* and the plurality of second bars **338***c* of the second electrode **338** to cause the disclination. As a result, the brightness of the black image may increase due to the disclination.

[0112] To prevent increase of the brightness of the black image, the black matrix **352** includes first, second, third and fourth blocking parts **352***a*, **352***b*, **352***c* and **352***d*. The first blocking part **352***a* has a bar shape along the second direction corresponding to the first and second connecting parts **338***b* and **338***d* of the second electrode **338**. The second blocking part **352***b* has a bar shape along the first direction corresponding to the central portion of the plurality of first bars **338***a* and the plurality of second bars **338***c* of the second electrode **338**. The third blocking part **352***c* has a bar shape along the first direction corresponding to the central portion of the first and second openings op**1** and op**2**. The fourth blocking part **352***d* has a bar shape along the second direction corresponding to the central portion of the third opening op**3**.

[0113] As a result, the black matrix **352** has a lattice shape including the first, second, third and fourth blocking parts **352***a*, **352***b*, **352***c* and **352***d* of bar shapes connected to each other and along the first and second directions. The first, second, third and fourth blocking parts **352***a*, **352***b*, **352***c* and **352***d* constitute a fourth opening op**4** exposing edge portions of the plurality of first bars **338***a* and the plurality of second bars **338***c* of the second electrode **338**.

[0114] Each of the second and third blocking parts **352***b* and **352***c* of the black matrix **352** may have a third width w**3** substantially the same as a width of the disclination.

[0115] For example, when each of the plurality of first bars **338***a* and the plurality of second bars **338***c* of the second electrode **338** has a first width w**1**, the third width w**3** of each of the second and third blocking parts **352***b* and **352***c* of the black matrix **352** may be within a range of about 25% to about 50% of the first width w**1**.

[0116] The liquid crystal layer **360** includes a plurality of liquid crystal molecules **362**. The liquid crystal molecule **362** on an edge portion of the plurality of first bars **338***a* and the plurality of second bars **338***c* of the second electrode **338** may have a first tilt angle al with respect to the first substrate **320** and have a first twist angle b**1** with respect to the first direction after an electric field is generated.

[0117] The liquid crystal layer **360** may be initially aligned along the first direction and the plurality of liquid crystal molecules **362** may have a positive dielectric anisotropy ($\Delta\varepsilon>0$). Alternatively, the liquid crystal layer **360** may be initially aligned along the second direction and the plurality of liquid crystal molecules **362** may have a negative dielectric anisotropy ($\Delta\varepsilon<0$).

[0118] In the LCD device **310**, a voltage is applied to the first and second electrodes **334** and **338** to generate an electric field. An electric field along the second direction may be generated at a side extending along the first direction of the plurality of first bars **338***a* and the plurality of second bars **338***c*, and an electric field along the first direction may be generated at a side extending along the second direction of the plurality of first bars **338***a* and the plurality of second bars **338***c* and a side extending along the second direction of the first and second connecting parts **338***b* and **338***d*. An electric field along a diagonal direction between the first and second directions may be generated at a corner portion of the first, second and third openings op**1**, op**2** and op**3**.

[0119] The liquid crystal molecule **362** at the corner portion of the first, second and third openings op**1**, op**2** and op**3**, which is disposed along the first direction before the voltage is applied, rotates in preference to a clockwise direction or a counterclockwise direction by the electric field along the diagonal direction to be promptly realigned after the voltage is applied.

[0120] The liquid crystal molecule **362** at the side along the first direction of the plurality of first bars **338***a* and the plurality of second bars **338***c*, which is extended along the first direction before the voltage is applied, rotates without preference to a clockwise direction or a counterclockwise direction by the electric field along the second direction to be realigned after the voltage is applied. The liquid crystal molecule **362** at the side along the first direction of the plurality of first bars **338***a* and the plurality of second bars **338***c* is promptly realigned due to the realigned liquid crystal molecule **362** at the corner portion of the first, second and third openings op**1**, op**2** and op**3**.

[0121] Accordingly, in the LCD device **310** according to the third embodiment, the liquid crystal layer **360** is driven by the electric field generated between the first and second electrodes **334** and **338**. The liquid crystal molecule **362** at the corner portion of the first, second and third openings op**1**, op**2** and op**3** is promptly realigned in preference to a rotational direction, and the liquid crystal molecule **362** at the side along the first direction of the plurality of first bars **338***a* and the plurality of second bars **338***c* is promptly realigned due to the realignment of the liquid crystal molecule **362** at the corner portion of the first, second and third openings op**1**, op**2** and op**3**. As a result, a response time defined as a sum of a rising time and a falling time of the liquid crystal molecule **362** is reduced and a response speed increases. Therefore, the LCD device **310** may be easily applied to virtual reality (VR) equipment.

[0122] For example, the rising time, the falling time and the response time of the liquid crystal molecule **362** may be about 4.1 msec, about 3.8 msec and about 7.9 msec, respectively.

[0123] In addition, since the disclination corresponding to the central portion of the second electrode **338** and the central portion of the first, second and third openings op**1**, op**2** and op**3** is blocked by the black matrix **352**, a contrast ratio increases.

[0124] FIG. **11** is a graph showing a contrast ratio and a white luminance with respect to a width of a black matrix of a liquid crystal display device according to a third embodiment of the present disclosure, and FIG. **12** is a table illustrating a contrast ratio and a white luminance with respect to a width of a black matrix of a liquid crystal display device according to a third embodiment of the present disclosure. Reference is made to FIGS. **9** and **10** with FIGS. **11** and **12**.

[0125] In FIGS. **11** and **12**, since a light leakage through the disclination of the central portion of the second electrode **338** and the central portion of the first, second and third openings op**1**, op**2** and op**3** is prevented by the second, third and fourth blocking parts **352***b*, **352***c* and **352***d* of the black matrix **352**, a black luminance of the LCD device **310** according to the third embodiment of the present disclosure is reduced and the contrast ratio (CR) of the LCD device **310** according to the third embodiment of the present disclosure increases as compared with the LCD device **110** according to the first embodiment.

[0126] The contrast ratio increases as the width of the second, third and fourth blocking parts **352***b*, **352***c* and **352***d* of the black matrix **352** increases.

[0127] For example, when the third width w**3** of the second and third blocking parts **352***b* and **352***c* of the black matrix **352** is about 0.4 μm, about 0.8 μm, about 1.2 μm, about 1.5 μm, about 2.0 μm, about 2.3 μm and about 2.5 μm, the contrast ratio of the LCD device **310** of the third embodiment may be about 108.0%, about 119.7%, about 127.7%, about 134.9%, about 145.6%, about 149.3% and about 152.2%, respectively, as compared with the contrast ratio of 100% of the LCCD device **110** of the first embodiment. As a result, the contrast ratio of the LCD device **310** of the third embodiment may increase by about 8.0%, about 19.7%, about 27.7%, about 34.9%, about 45.6%, about 49.3% and 52.2%, respectively, as compared with the LCD device **110** of the first embodiment.

[0128] Although a white luminance (WL) may be reduced by the black matrix **352**, reduction in the white luminance to an acceptable level may be offset by the increase of the contrast ratio.

[0129] In addition, reduction in the white luminance may be minimized by applying the black matrix **352** of the third embodiment to the LCD device **210** of the second embodiment where the transmittance and the brightness are improved.

[0130] In the LCD device **310** according to the third embodiment of the present disclosure, since the liquid crystal layer **360** is driven by using the first electrode **334** of a plate shape and the second electrode **338** including the plurality first bars **338***a* and the plurality of second bars **338***c*, a response time defined as a sum of a rising time and a falling time of the liquid crystal molecule **362** is reduced and a response speed increases. Therefore, the LCD device **310** may be easily applied to virtual reality (VR) equipment.

[0131] Further, since the light leakage through the disclination is prevented by the black matrix **352** corresponding to the central portion of the plurality of first bars **338***a* and the plurality of second bars **338***c* of the second electrode **338** and the central portion of the first, second and third openings op**1**, op**2** and op**3**, the contrast ratio of the LCD device **310** increases.

[0132] In another embodiment, to improve reduction of the transmittance and the white luminance due to the disclination of the LCD device **110** of the first embodiment, first and second liquid crystal capsule layers **468** and **482** (of FIG. **13**) functioning as a quarter wave plate (QWP) in an ON state may be formed on outer surfaces of the first and second substrates **120** and **150**, respectively.

[0133] FIG. **13** is a cross-sectional view showing a liquid crystal display device according to a fourth embodiment of the present disclosure, and FIG. **14** is a plan view showing a second electrode, first and second capsule electrodes and third and fourth capsule electrodes of a liquid crystal display device according to a fourth embodiment of the present disclosure. Illustration of parts the same as the first embodiment may be omitted.

[0134] In FIGS. **13** and **14**, a liquid crystal display (LCD) device **410** according to a fourth embodiment of the present disclosure includes first and second substrates **420** and **450** facing and spaced apart from each other, a liquid crystal layer **460** between the first and second substrates **420** and **450**, a first liquid crystal capsule layer **468** and a first polarizing plate **476** sequentially on an outer surface of the first substrate **420**, and a second liquid crystal capsule layer **482** and a second polarizing plate **490** sequentially on an outer surface of the second substrate **450**. The first and second substrates **420** and **450** include a plurality of pixel regions P.

[0135] A thin film transistor (TFT) T and first and second electrodes **434** and **438** are disposed in each of the plurality of pixel regions P on an inner surface of the first substrate **420**. A gate electrode **422** is disposed in each of the plurality of pixel regions P on the inner surface of the first substrate **420**, and a gate insulating layer **424** is disposed on the gate electrode **422** in a whole of the first substrate **420**.

[0136] A semiconductor layer **426** is disposed on the gate insulating layer **424** corresponding to the gate electrode **422**, and a source electrode **428** and a drain electrode **430** spaced apart from each other are disposed on both end portions of the semiconductor layer **426**.

[0137] The gate electrode **422**, the semiconductor layer **426**, the source electrode **428** and the drain electrode **430** constitute the TFT T.

[0138] Although not shown, a gate line and a data line are disposed over the first substrate **420** and the TFT T is connected to the gate line and the data line. The gate line and the data line cross each other to form the pixel region P adjacent to the crossing location.

[0139] A first insulating layer **432** is disposed on the TFT T in a whole of the first substrate **420**, and a first electrode **434** of a plate shape is disposed on the first insulating layer **432** in each pixel region P.

[0140] A second insulating layer **436** is disposed on the first electrode **434** in a whole of the first substrate **420**, and a second electrode **438** of a bar shape is disposed on the second insulating layer **436** corresponding to the first electrode **434**.

[0141] The second electrode **438** is connected to the drain electrode **430** of the TFT T through a drain contact hole of the first and second insulating layers **432** and **436**. The second electrode **438** may include a plurality of first bars **438***a*, a first connecting part **438***b*, a plurality of second bars **438***c* and a second connecting part **438***d*. The plurality of first bars **438***a* are extended along a first direction X parallel to the gate line. The first connecting part **438***b* connects the plurality of first bars **438***a* and is extended along a second direction Y parallel to the data line. The plurality of second bars **438***c* are symmetric to the plurality of first bars **438***a* with respect to a central line of the pixel region P and are extended along the first direction X. The second connecting part **438***d* connects the plurality of second bars **438***c* and is extended along the second direction Y.

[0142] The second electrode **438** has a first opening op**1** between the plurality of first bars **438***a*, a second opening op**2** between the plurality of second bars **438***c* and a third opening op**3** between the plurality of first bars **438***a* and the plurality of second bars **438***c*.

[0143] For example, a length of a side extending along the second direction of the first and second openings op**1** and op**2**, which is a gap distance between adjacent two of the plurality of first bars **438***a* and is a gap distance between adjacent two of the plurality of second bars **438***c*, may be about 1 μm to about 5 μm.

[0144] A length of a side along the first direction X of the third opening op**3**, which is a gap distance between the plurality of first bars **438***a* and the plurality of second bars **438***c*, may be about 3% to about 15% of a length of a side along the first direction X of the pixel region P and may be about 5% to about 20% of a length of a side along the first direction X of the second electrode **438**. For example, the length of a side along the first direction X of the third opening op**3** may be about 1 μm to about 5 μm.

[0145] Although the first electrode **434** is a common electrode and the second electrode **438** is a pixel electrode connected to the TFT T in the fourth embodiment, the first electrode **434** may be a pixel electrode connected to the TFT T and the second electrode **438** may be a common electrode in another embodiment.

[0146] The liquid crystal layer **460** includes a plurality of liquid crystal molecules **462**. The liquid crystal molecule **462** on an edge portion of the plurality of first bars **438***a* and the plurality of second bars **438***c* of the second electrode **438** may have a first tilt angle a**1** with respect to the first substrate **420** and have a first twist angle b**1** with respect to the first direction X after an electric field is generated.

[0147] The liquid crystal layer **460** may be initially aligned along the first direction X and the plurality of liquid crystal molecules **462** may have a positive dielectric anisotropy ($\Delta\varepsilon>0$). Alternatively, the liquid crystal layer **460** may be initially aligned along the second direction Y and the plurality of liquid crystal molecules **462** may have a negative dielectric anisotropy ($\Delta\varepsilon<0$).

[0148] First and second capsule electrodes **464** and **466** each having a bar shape are disposed on an outer surface of the first substrate **420**, and a first liquid crystal capsule layer **468** is disposed on the first and second capsule electrodes **464** and **466**. The first and second capsule electrodes **464** and **466** are parallel to and spaced apart from each other.

[0149] Each of the first and second capsule electrodes **464** and **466** may be obliquely disposed to have a first oblique angle C**1** with respect to the first direction X. For example, the first oblique angle C**1** may be about 45 degrees.

[0150] The first liquid crystal capsule layer **468** includes a first binder **470** and a plurality of first liquid crystal capsules **472** dispersed in the first binder **470**. Each of the plurality of first liquid crystal capsules **472** includes a plurality of first liquid crystal molecules **474**.

[0151] A thickness of the first liquid crystal capsule layer **468** may be changed according to a birefringence property and an optical transmittance of the first liquid crystal capsule **472**. For example, the thickness of the first liquid crystal capsule layer **468** may be within a range of about 1 μm to about 6 μm.

[0152] The first binder **470** disperses the plurality of first liquid crystal capsules **472**. For example, the first binder **470** may be transparent or translucent (e.g., half-transparent) and may have a water solubility, a fat solubility or a mixed property of a water solubility and a fat solubility.

[0153] Each of the plurality of first liquid crystal capsules **472** is a polymer capsule having a diameter of 1 to 999 nanometers and includes a water soluble material such as poly vinyl alcohol (PVA) or a fat soluble material such as poly methyl methacrylate (PMMA). Each of the plurality of first liquid crystal capsules **472** may have a diameter within a range of about 1 nm to about 320 nm.

[0154] The plurality of first liquid crystal molecules **474** may include at least one of a nematic liquid crystal, a ferroelectric liquid crystal and a flexo electric liquid crystal.

[0155] Since the first liquid crystal capsule layer **468** including the first binder **470** and the plurality of first liquid crystal capsules **472** may be formed without an additional orientation layer, the first liquid crystal capsule layer **468** may directly contact the first and second capsule electrodes **464** and **466**.

[0156] The plurality of first liquid crystal molecules **474** may be initially randomly aligned in the plurality of first liquid crystal capsules **472** such that a long axis of each first liquid crystal molecule **474** forms a random angle with respect to a normal line of the first substrate **420** (e.g., initial random alignment).

[0157] A first polarizing plate **476** is disposed on the first liquid crystal capsule layer **468**. The first polarizing plate **476** may be a linear polarizing plate where a transmission axis is parallel to the first direction X.

[0158] Third and fourth capsule electrodes **478** and **480** each having a bar shape are disposed on an outer surface of the second substrate **450**, and a second liquid crystal capsule layer **482** is disposed on the third and fourth capsule electrodes **478** and **480**. The third and fourth capsule electrodes **478** and **480** are parallel to and spaced apart from each other.

[0159] Each of the third and fourth capsule electrodes **478** and **480** may be obliquely disposed to have a second oblique angle C**2** with respect to the first direction X. The first and second oblique angles C**1** and C**2** may be different from each other. For example, the second oblique angle C**2** may be about 135 degrees.

[0160] The second liquid crystal capsule layer **482** includes a second binder **484** and a plurality of second liquid crystal capsules **486** dispersed in the second binder **484**. Each of the plurality of second liquid crystal capsules **486** includes a plurality of second liquid crystal molecules **488**.

[0161] A thickness of the second liquid crystal capsule layer **482** may be changed according to a birefringence property and an optical transmittance of the second liquid crystal capsule **486**. For example, the thickness of the second liquid crystal capsule layer **482** may be within a range of about 1 μm to about 6 μm.

[0162] The second binder **484** disperses the plurality of second liquid crystal capsules **486**. For example, the second binder **484** may be transparent or translucent (e.g., half-transparent) and may have a water solubility, a fat solubility or a mixed property of a water solubility and a fat solubility.

[0163] Each of the plurality of second liquid crystal capsules **486** is a polymer capsule having a diameter of 1 to 999 nanometers and includes a water soluble material such as poly vinyl alcohol (PVA) or a fat soluble material such as poly methyl methacrylate (PMMA). Each of the plurality of second liquid crystal capsules **486** may have a diameter within a range of about 1 nm to about 320 nm.

[0164] The plurality of second liquid crystal molecules **488** may include at least one of a nematic liquid crystal, a ferroelectric liquid crystal and a flexo electric liquid crystal.

[0165] Since the second liquid crystal capsule layer **482** including the second binder **484** and the plurality of second liquid crystal capsules **486** may be formed without an additional orientation layer, the second liquid crystal capsule layer **482** may directly contact the third and fourth capsule electrodes **478** and **480**.

[0166] The plurality of second liquid crystal molecules **488** may be initially randomly aligned in the plurality of second liquid crystal capsules **486** such that a long axis of each second liquid crystal molecule **488** forms a random angle with respect to a normal line of the second substrate **450** (e.g., initial random alignment).

[0167] The first and second binders **470** and **484** may be the same as or different from each other, the first and second liquid crystal capsules **472** and **486** may be the same as or different from each other, and the first and second liquid crystal molecules **474** and **488** may be the same as or different from each other.

[0168] A second polarizing plate **490** is disposed on the second liquid crystal capsule layer **482**. The second polarizing plate **490** may be a linear polarizing plate where a transmission axis is parallel to the second direction Y.

[0169] In the LCD device **410**, a voltage is applied to the first and second electrodes **434** and **438** to generate an electric field. An electric field along the second direction Y may be generated at a side along the first direction X of the plurality of first bars **438***a* and the plurality of second bars **438***c*, and an electric field along the first direction X may be generated at a side along the second direction Y of the plurality of first bars **438***a* and the plurality of second bars **438***c* and a side along the second direction Y of the first and second connecting parts **438***b* and **438***d*. An electric field along a diagonal direction between the first and second directions X and Y may be generated at a corner portion of the first, second and third openings op**1**, op**2** and op**3**.

[0170] The liquid crystal molecule **462** at the corner portion of the first, second and third openings op**1**, op**2** and op**3**, which is disposed along the first direction X before the voltage is applied, rotates in preference to a clockwise direction or a counterclockwise direction by the electric field along the diagonal direction to be promptly realigned after the voltage is applied.

[0171] The liquid crystal molecule **462** at the side along the first direction X of the plurality of first bars **438***a* and the plurality of second bars **438***c*, which is extended along the first direction X before the voltage is applied, rotates without preference to a clockwise direction or a counterclockwise direction by the electric field along the second direction Y to be realigned after the voltage is applied. The liquid crystal molecule **462** at the side along the first direction X of the plurality of first bars **438***a* and the plurality of second bars **438***c* is promptly realigned due to the realigned liquid crystal molecule **462** at the corner portion of the first, second and third openings op**1**, op**2** and op**3**.

[0172] Accordingly, in the LCD device **410** according to the fourth embodiment, the liquid crystal layer **460** is driven by the electric field generated between the first and second electrodes **434** and **438**. The liquid crystal molecule **462** at the corner portion of the first, second and third openings op**1**, op**2** and op**3** is promptly realigned in preference to a rotational direction, and the liquid crystal molecule **462** at the side along the first direction X of the plurality of first bars **438***a* and the plurality of second bars **438***c* is promptly realigned due to the realignment of the liquid crystal molecule **462** at the corner portion of the first, second and third openings op**1**, op**2** and op**3**. As a result, a response time defined as a sum of a rising time and a falling time of the liquid crystal molecule **462** is reduced and a response speed increases. Therefore, the LCD device **410** may be easily applied to virtual reality (VR) equipment.

[0173] For example, the rising time, the falling time and the response time of the liquid crystal molecule **462** may be about 4.1 msec, about 3.8 msec and about 7.9 msec, respectively.

[0174] In addition, since the first and second liquid crystal capsule layers **468** and **482** on the outer surfaces of the first and second substrates **420** and **450** are used as a quarter wave plate (QWP), a light is transmitted even through the disclination.

[0175] FIGS. **15**A and **15**B are cross-sectional views showing a polarization state of an ON state and an OFF state, respectively, of a liquid crystal display device according to a fourth embodiment of the present disclosure. Reference is made to FIGS. **13** and **14** with FIGS. **15**A and **15**B. For convenience of illustration, only the first and second polarizing plates **476** and **490**, the first and second liquid crystal capsule layers **468** and **482** and the liquid crystal layer **460** influencing the polarization state are shown in FIGS. **15**A and **15**B.

[0176] In FIG. **15**A, when the LCD device **410** has an ON state where a white image is displayed, a backlight unit (not shown) under the first polarizing plate **476** transmits a light of a first polarization state PS**1** of non-polarization to the first polarizing plate **476** having a transmission axis parallel to the first direction X.

[0177] A light of linear polarization parallel to the transmission axis of the first polarizing plate **476** among the light of the first polarization state PS**1** selectively passes through the first polarizing plate **476**, and the first polarizing plate **476** transmits a light of a second polarization state PS**2** of linear polarization parallel to the first direction X to the first liquid crystal capsule layer **468**.

[0178] In the ON state, a first capsule voltage is applied to the first and second capsule electrodes **464** and **466** to generate a horizontal electric field between the first and second capsule electrodes **464** and **466**. As a result, the plurality of first liquid crystal molecules **474** of the plurality of first liquid crystal capsules **472** may be aligned parallel to the horizontal electric field, and the first liquid crystal capsule layer **468** may operate as a quarter wave plate (QWP) having a retardation of $\lambda/4$ (λ is a wavelength of a light).

[0179] Since the QWP modifies a light of linear polarization to a light of circular polarization, the first liquid crystal capsule layer **468** functioning as the QWP may modify the light of the second polarization state PS**2** of linear polarization to a light of a third polarization state PS**3** of left-handed circular polarization and may transmit the light of the third polarization state PS**3** to the liquid crystal layer **460**.

[0180] In the ON state, a driving voltage is applied to the first and second electrodes **434** and **438** to generate a horizontal electric field between the first and second electrodes **434** and **438**. As a result, the plurality of liquid crystal molecules **462** may be aligned parallel to the horizontal electric field, and the liquid crystal layer **460** may have a retardation of $\lambda/2$ (λ is a wavelength of a light).

[0181] Since the horizontal electric field is not generated in the liquid crystal layer **460** corresponding to the central portion of the plurality of first bars **438***a* and the plurality of second bars **438***c* of the second electrode **438** and the central portion of the first, second and third openings op**1**, op**2** and op**3**, the plurality of liquid crystal molecules **462** are not normally aligned. As a result, an incident light of linear polarization may not pass through the liquid crystal layer **460** corresponding to the central portion of the plurality of first bars **438***a* and the plurality of second bars **438***c* of the second electrode **438** and the central portion of the first, second and third openings op**1**, op**2** and op**3** to be displayed as a disclination.

[0182] However, in the LCD device **410** according to the fourth embodiment, since the light of the third polarization state PS**3** of left-handed circular polarization is transmitted to the liquid crystal layer **460** of the ON state, the incident light of the third polarization state PS**3** may pass through a whole region of the liquid crystal layer **460** including the central portion of the plurality of first bars **438***a* and the plurality of second bars **438***c* of the second electrode **438** and the central portion of the first, second and third openings op**1**, op**2** and op**3**. As a result, the disclination may be prevented in the LCD device **410** of the ON state.

[0183] In addition, the liquid crystal layer **460** having the retardation of λ/2 may modify the light of the third polarization state PS**3** of left-handed circular polarization to a light of a fourth polarization state PS**4** of right-handed circular polarization and may transmit the light of the fourth polarization state PS**4** to the second liquid crystal capsule layer **482**.

[0184] In the ON state, a second capsule voltage is applied to the third and fourth capsule electrodes **478** and **480** to generate a horizontal electric field between the third and fourth capsule electrodes **478** and **480**. As a result, the plurality of second liquid crystal molecules **488** of the plurality of second liquid crystal capsules **486** may be aligned parallel to the horizontal electric field, and the second liquid crystal capsule layer **482** may operate as a quarter wave plate (QWP) having a retardation of λ/4 (λ is a wavelength of a light).

[0185] Since the QWP modifies a light of circular polarization to a light of linear polarization, the second liquid crystal capsule layer **482** functioning as the QWP may modify the light of the fourth polarization state PS**4** of right-handed circular polarization to a light of a fifth polarization state PS**5** of linear polarization parallel to the second direction Y and may transmit the light of the fifth polarization state PS**5** to the second polarizing plate **490**.

[0186] A whole of the light of the fifth polarization state PS**5** passes through the second polarizing plate **490** having a transmission axis parallel to the second direction Y, and the LCD device **410** may display a white.

[0187] In FIG. **15**B, when the LCD device **410** has an OFF state where a black image is displayed, a backlight unit (not shown) under the first polarizing plate **476** transmits a light of a first polarization state PS**1** of non-polarization to the first polarizing plate **476** having a transmission axis parallel to the first direction X.

[0188] A light of linear polarization parallel to the transmission axis of the first polarizing plate **476** among the light of the first polarization state PS**1** selectively passes through the first polarizing plate **476**, and the first polarizing plate **476** transmits a light of a second polarization state PS**2** of linear polarization parallel to the first direction X to the first liquid crystal capsule layer **468**.

[0189] In the OFF state, a first capsule voltage is not applied to the first and second capsule electrodes **464** and **466** not to generate a horizontal electric field between the first and second capsule electrodes **464** and **466**. As a result, the plurality of first liquid crystal molecules **474** of the plurality of first liquid crystal capsules **472** may maintain the initial random alignment, and the first liquid crystal capsule layer **468** may intactly transmit the light of the second polarization state PS**2** of linear polarization parallel to the first direction X to the liquid crystal layer **460**.

[0190] In the OFF state, a driving voltage is not applied to the first and second electrodes **434** and **438** not to generate a horizontal electric field between the first and second electrodes **434** and **438**. As a result, the plurality of liquid crystal molecules **462** may maintain an initial alignment, and the liquid crystal layer **460** may intactly transmit the light of the second polarization state PS**2** of linear polarization parallel to the first direction X to the second liquid crystal capsule layer **482**.

[0191] In the OFF state, a second capsule voltage is not applied to the third and fourth capsule electrodes **478** and **480** not to generate a horizontal electric field between the third and fourth capsule electrodes **478** and **480**. As a result, the plurality of second liquid crystal molecules **488** of the plurality of second liquid crystal capsules **486** may maintain the initial random alignment, and the second liquid crystal capsule layer **482** may intactly transmit the light of the second polarization state PS**2** of linear polarization parallel to the first direction X to the second polarizing plate **490**.

[0192] A whole of the light of the second polarization state PS**2** of linear polarization parallel to the first direction X is absorbed by the second polarizing plate **490** having a transmission axis parallel to the second direction Y, and the LCD device **410** may display black without a light leakage.

[0193] In the LCD device **410** according to the fourth embodiment of the present disclosure, since the liquid crystal layer **460** is driven by using the first electrode **434** of a plate shape and the second electrode **438** including the plurality first bars **438***a* and the plurality of second bars **438***c*, a response time defined as a sum of a rising time and a falling time of the liquid crystal molecule **362** is reduced and a response speed increases. Therefore, the LCD device **310** may be easily applied to virtual reality (VR) equipment.

[0194] Further, in the ON state, since the first and second liquid crystal capsule layers **468** and **482** on the outer surfaces of the first and second substrates **420** and **450** function as the QWP such that the light of circular polarization passes through the liquid crystal layer **460**, the light may be transmitted through the whole of the pixel region P including the disclination. As a result, transmittance and white luminance of the LCD device **410** may be improved.

[0195] Moreover, in the OFF state, since the first and second liquid crystal capsule layers **468** and **482** on the outer surfaces of the first and second substrates **420** and **450** have no retardation such that the light of linear polarization passes through the liquid crystal layer **460**, a light leakage may be prevented. As a result, reduction of a contrast ratio may be prevented.

[0196] Consequently, in a liquid crystal display device according to the present disclosure, since a dielectric pattern having the same shape as an electrode is formed on the electrode having a plurality of openings, a tilt angle of a liquid crystal molecule is reduced and a twist angle of the liquid crystal molecule is increased. As a result, brightness is increased.

[0197] In addition, by forming a black matrix having a lattice shape disposed on the electrode and the opening, the response time is reduced and the brightness and the transmittance is increased. Further, black luminance is reduced and contrast ratio increased.

[0198] Further, since first and second liquid crystal capsule layers functioning as a quarter wave plate in an ON state is formed on outer surfaces of first and second substrates, the response time is reduced and the transmittance and the white luminance is increased.

[0199] It will be apparent to those skilled in the art that various modifications and variations can be made in the display device of the present disclosure without departing from the technical idea or scope of the disclosure. Thus, it is intended that the present disclosure cover the modifications and variations of this disclosure provided they come within the scope of the appended claims and their equivalents.

[0200] The various embodiments described above can be combined to provide further embodiments. All of the U.S. patents, U.S. patent application publications, U.S. patent applications, foreign patents, foreign patent applications and non-patent publications referred to in this specification and/or listed in the Application Data Sheet are incorporated herein by reference, in their entirety. Aspects of the embodiments can be modified, if necessary to employ concepts of the various patents, applications and publications to provide yet further embodiments.

[0201] These and other changes can be made to the embodiments in light of the above-detailed description. In general, in the following claims, the terms used should not be construed to limit the claims to the specific embodiments disclosed in the specification and the claims, but should be construed to include all possible embodiments along with the full scope of equivalents to which such claims are entitled. Accordingly, the claims are not limited by the disclosure.

1. A liquid crystal display device, comprising:

first and second substrates facing and spaced apart from each other, the first and second substrates having a pixel region;

a gate line and a data line on an inner surface of the first substrate, the gate line and the data line crossing each other adjacent to the pixel region;

a thin film transistor connected to the gate line and the data line in the pixel region;

a first electrode disposed above the thin film transistor;

a second electrode being partially disposed over the first electrode; and

a liquid crystal layer between the first and second substrates,

wherein the second electrode comprises:

a plurality of first bars spaced apart from each other and extending along a first direction parallel to the gate line;

a first connecting part connecting the plurality of first bars and extending along a second direction parallel to the data line;

a plurality of second bars symmetric to the plurality of first bars with respect to a central line of the pixel region, the plurality of second bars spaced apart from each other and extending along the first direction; and

a second connecting part connecting the plurality of second bars and extending along the second direction.

2. The display device of claim **1**, further comprising a dielectric pattern including an insulating material, the insulating material disposed on the second electrode.

3. The display device of claim **2**, wherein a shape of the insulating material of the dielectric pattern is a same as a shape of the second electrode.

4. The display device of claim **3**, wherein a thickness of the insulating material of the dielectric pattern is a same as a thickness of the second electrode.

5. The display device of claim **3**, wherein a width of the dielectric pattern is within a range of about 25% to 50% of a width of the second electrode.

6. The display device of claim **3**, wherein a gap distance between the plurality of first bars and the plurality of second bars is within a range of about 3% to 15% of a length of a side extending along the first direction of the pixel region.

7. The display device of claim **2**, wherein the insulating material of the dielectric pattern includes at least one of an inorganic insulating material and an organic insulating material.

8. The display device of claim **1**, further comprising a black matrix on an inner surface of the second substrate, the black matrix partially corresponding to a location of the second electrode and partially corresponding to a location of a plurality of openings of the second electrode.

9. The display device of claim **8**, wherein a first opening of the plurality of openings is formed between the plurality of first bars, a second opening of the plurality of openings is formed between the plurality of second bars, and a third opening of the plurality of openings is formed between the plurality of first bars and the plurality of second bars.

10. The display device of claim **9**, wherein the black matrix comprises:

a first blocking part partially corresponding to a location of the first and second connecting parts;

a second blocking part partially corresponding to locations of at least one of the plurality of first bars and at least one of the plurality of second bars;

a third blocking part partially corresponding to locations of the first and second openings; and

a fourth blocking part partially corresponding to a location of the third opening,

wherein the first, second, third and fourth blocking parts are connected to each other to constitute a fourth opening exposing an edge portion of the plurality of first bars and an edge portion of the plurality of second bars.

11. The display device of claim **10**, wherein the first blocking part partially corresponds to a location central to the first and second connecting parts;

the second blocking part partially corresponding to locations central of at least one of the plurality of first bars and at least one of the plurality of second bars;

the third blocking part partially corresponding to locations central of the first and second openings; and

the fourth blocking part partially corresponding to a location central of the third opening.

12. The display device of claim **1**, further comprising:

first and second capsule electrodes of a bar shape on an outer surface of the first substrate, the first and second capsule electrodes parallel to and spaced apart from each other;

a first liquid crystal capsule layer on the first and second capsule electrodes;

a first polarizing plate on the first liquid crystal capsule layer;

third and fourth capsule electrodes of a bar shape on an outer surface of the second substrate, the third and fourth capsule electrodes parallel to and spaced apart from each other;

a second liquid crystal capsule layer on the third and fourth capsule electrodes; and

a second polarizing plate on the second liquid crystal capsule layer.

13. The display device of claim **12**, wherein the first and second liquid crystal capsule layers operate as a quarter wave plate while a white image is displayed in the display device.

14. The display device of claim **12**, wherein the first liquid crystal capsule layer includes a first binder and a plurality of first liquid crystal capsules dispersed in the first binder,

wherein each of the plurality of first liquid crystal capsules includes a plurality of first liquid crystal molecules,

wherein the second liquid crystal capsule layer includes a second binder and a plurality of second liquid crystal capsules dispersed in the second binder, and

wherein each of the plurality of second liquid crystal capsules includes a plurality of second liquid crystal molecules.

15. The display device of claim **12**, wherein the first polarizing plate has a transmission axis parallel to the first direction,

wherein the first and second capsule electrodes are obliquely disposed to have a first oblique angle with respect to the first direction,

wherein the third and fourth capsule electrodes are obliquely disposed to have a second oblique angle different from the first oblique angle with respect to the first direction, and

wherein the second polarizing plate has a transmission axis parallel to the second direction.

16. The display device of claim **1**, wherein the first electrode is either one of a common electrode and a pixel electrode, and the second electrode is the other one of the common electrode and the pixel electrode.

17. The display device of claim **1**, wherein a plurality of liquid crystal molecules of the liquid crystal layer has a positive dielectric anisotropy ($\Delta\varepsilon>0$) when the liquid crystal layer is initially aligned along the first direction, and

wherein the plurality of liquid crystal molecules of the liquid crystal layer has a negative dielectric anisotropy ($\Delta\varepsilon<0$) when the liquid crystal layer is initially aligned along the second direction.

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申请(专利权)人(译)	LG DISPLAY CO. , LTD.		
当前申请(专利权)人(译)	LG DISPLAY CO. , LTD.		
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发明人	KIM, WON-TAECK EOM, YOU-HYUN AHN, SO-HYEONG JEONG, SONG-YI		
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摘要(译)

一种液晶显示装置，包括：第一基板和第二基板，彼此面对并且彼此间隔开，第一基板和第二基板具有像素区域;栅极线和数据线位于第一基板的内表面上，栅极线和数据线彼此交叉，与像素区域相邻;薄膜晶体管，连接到像素区域中的栅极线和数据线;薄膜晶体管上的板状第一电极;在第一电极上形成条形的第二电极;以及第一和第二基板之间的液晶层。