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(54) LIQUID CRYSTAL DISPLAY AND METHOD THEREOF

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

(57) **ABSTRACT**

A liquid crystal display ("LCD") includes first and second substrates facing each other, a plurality of pixel electrodes arranged in a matrix shape on the first substrate and including a stem and a plurality of minute branches obliquely extending from the stem, a common electrode facing the plurality of pixel electrodes, and a liquid crystal layer interposed between the first substrate and the second substrate and including a plurality of liquid crystal molecules, wherein the pixel electrodes are classified into a plurality of sub-regions according to a length direction of the minute branches, and the minute branches are protruded at edges of the sub-regions.

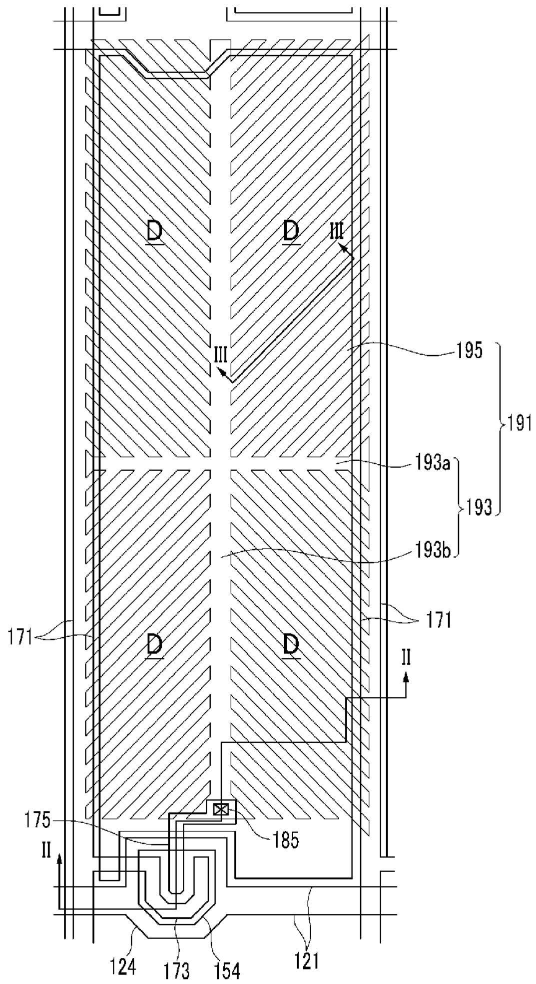


FIG.1

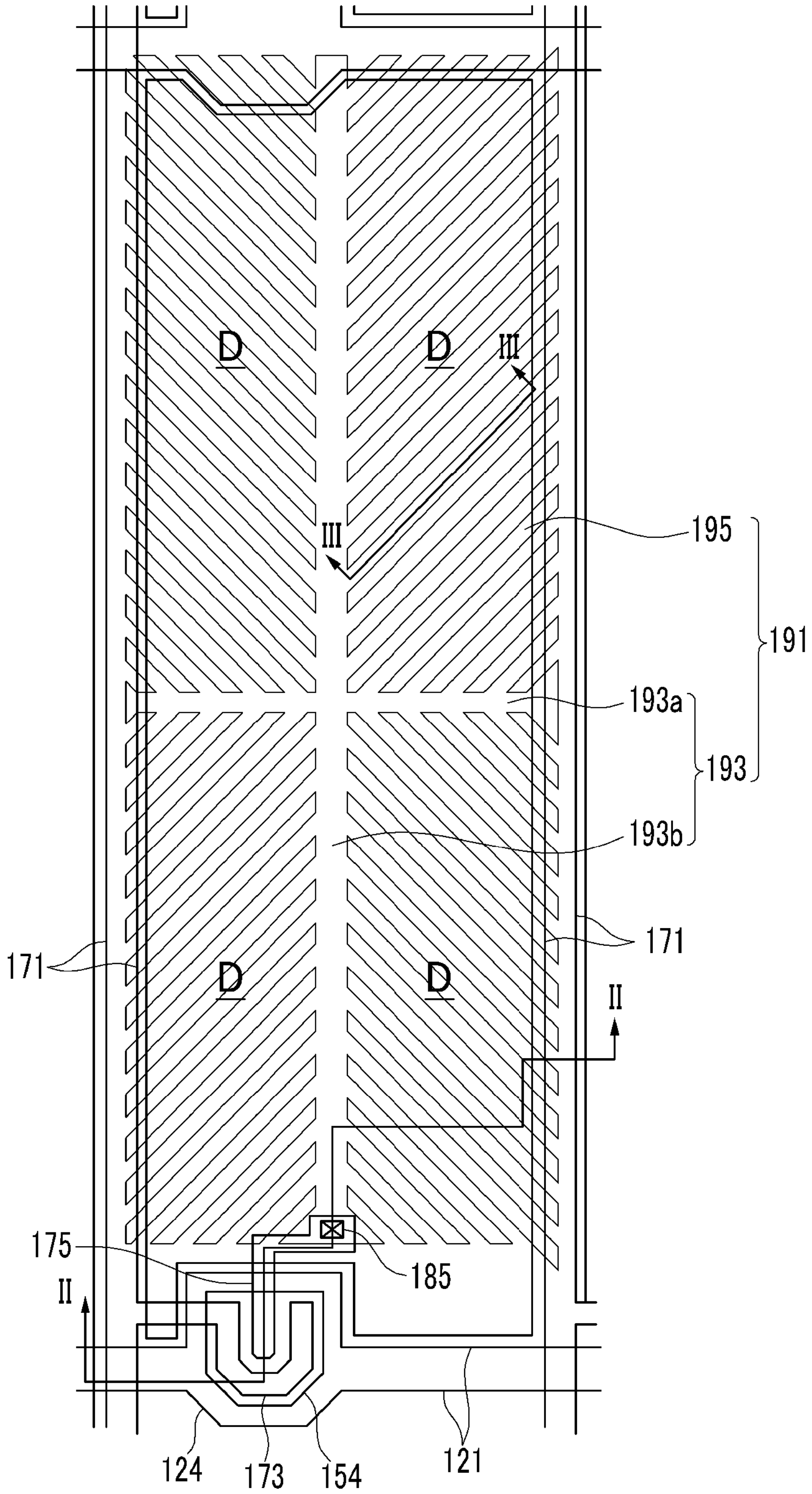
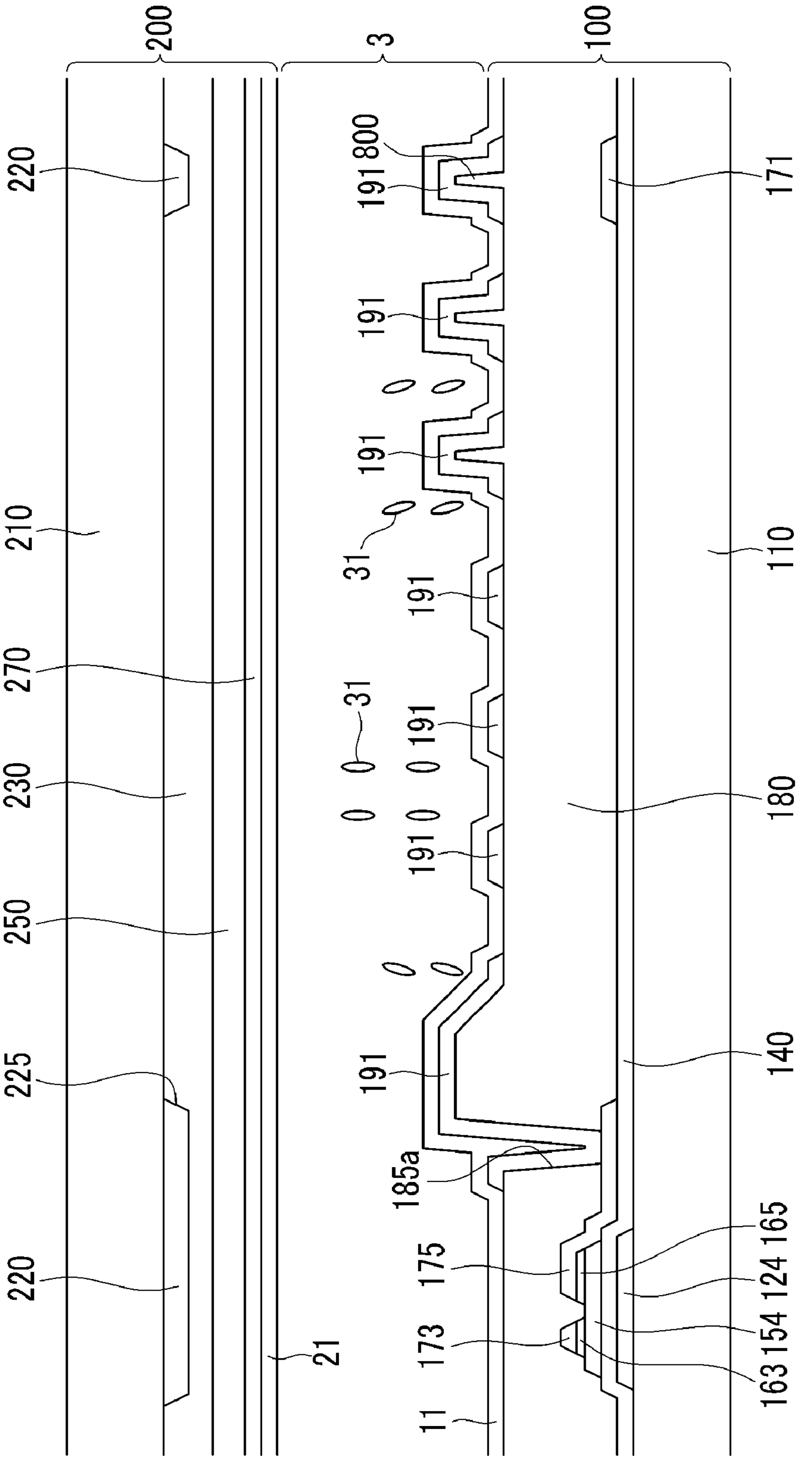

D
D
D
D
III
III
195
191
193a
193
193b
171
171
II
II
175
185
124
173
154
121

FIG.2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3
100
220
210
270
230
250
225
220
21
191
800
191
191
31
191
31
191
191
191
185a
175
173
11
171
110
180
140
165
124
154
163

FIG.3

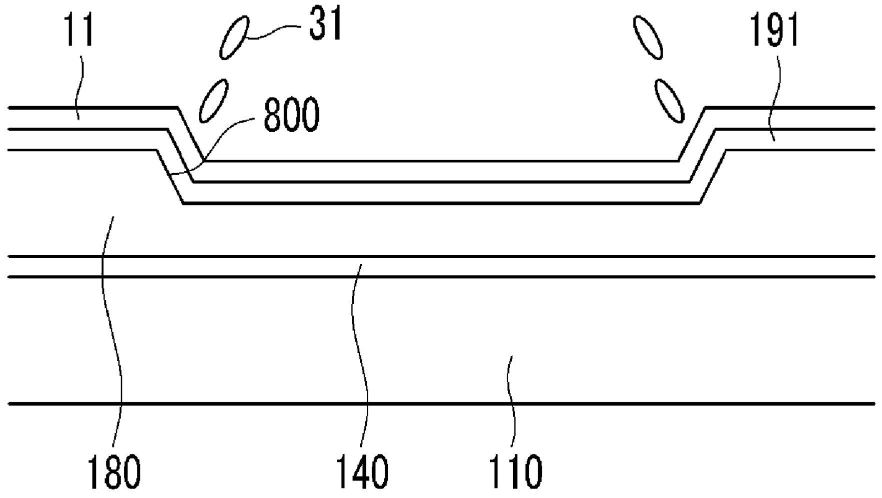


FIG.4

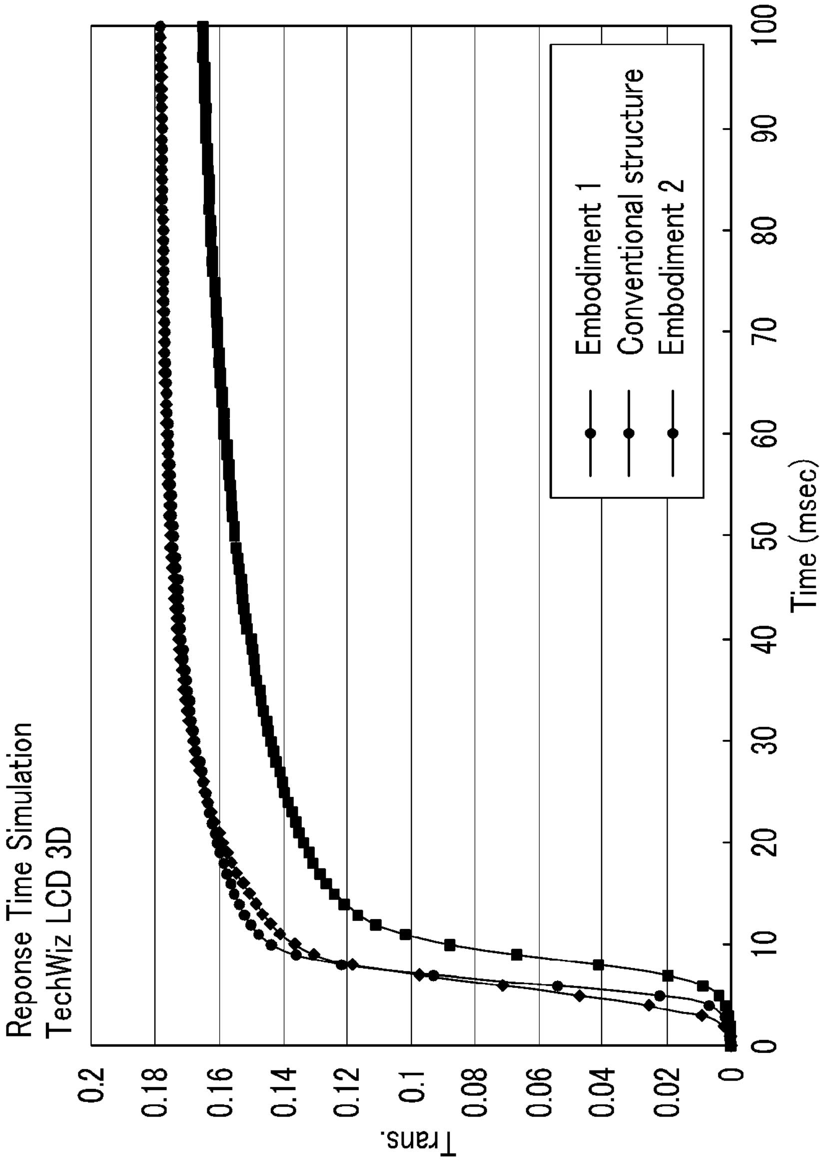

Reponse Time Simulation
TechWiz LCD 3D
Trans.
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
10
20
30
40
50
60
70
80
90
100
Time (msec)
Embodiment 1
Conventional structure
Embodiment 2

FIG.5

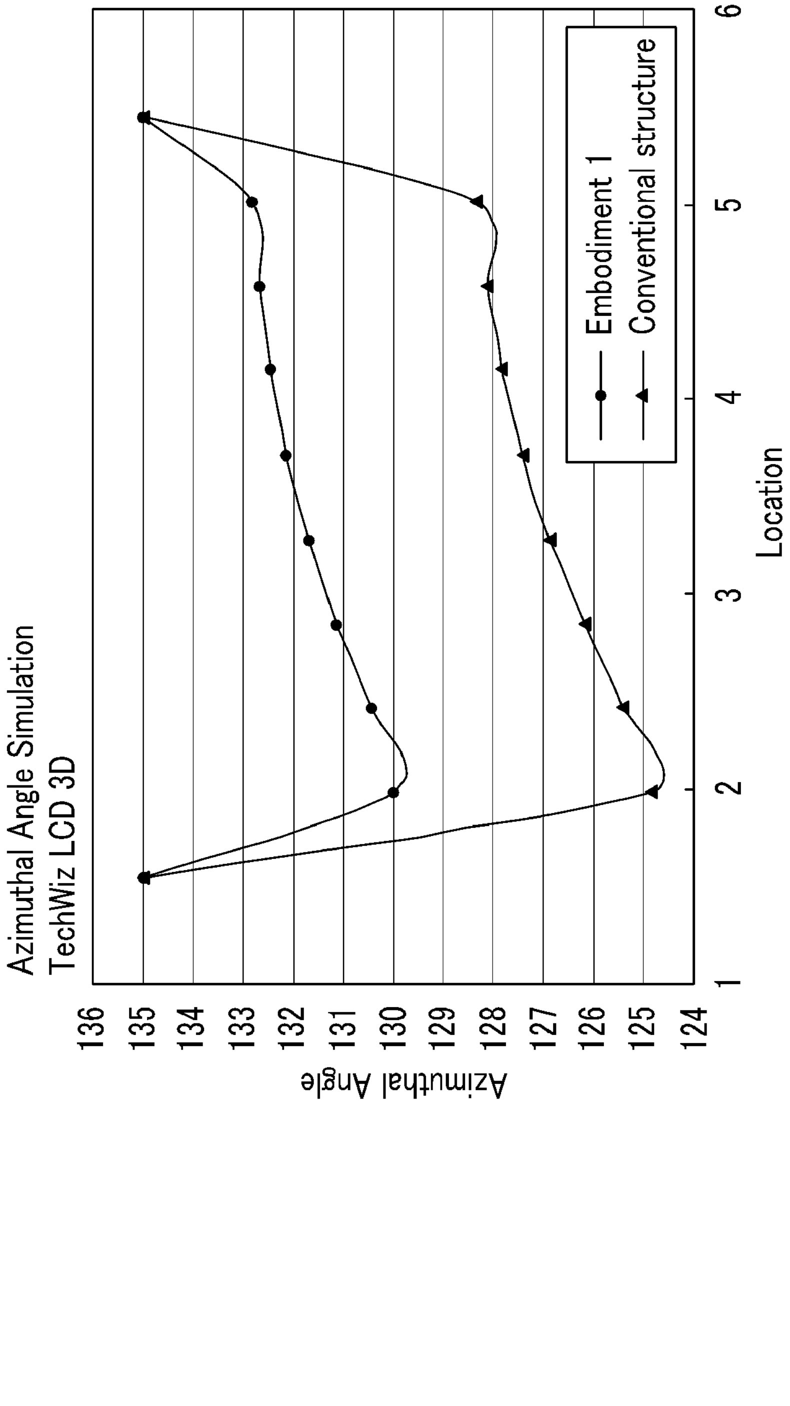

Azimuthal Angle Simulation
TechWiz LCD 3D
Azimuthal Angle
136
135
134
133
132
131
130
129
128
127
126
125
124
1
2
3
4
5
6
Location
Embodiment 1
Conventional structure

FIG.6

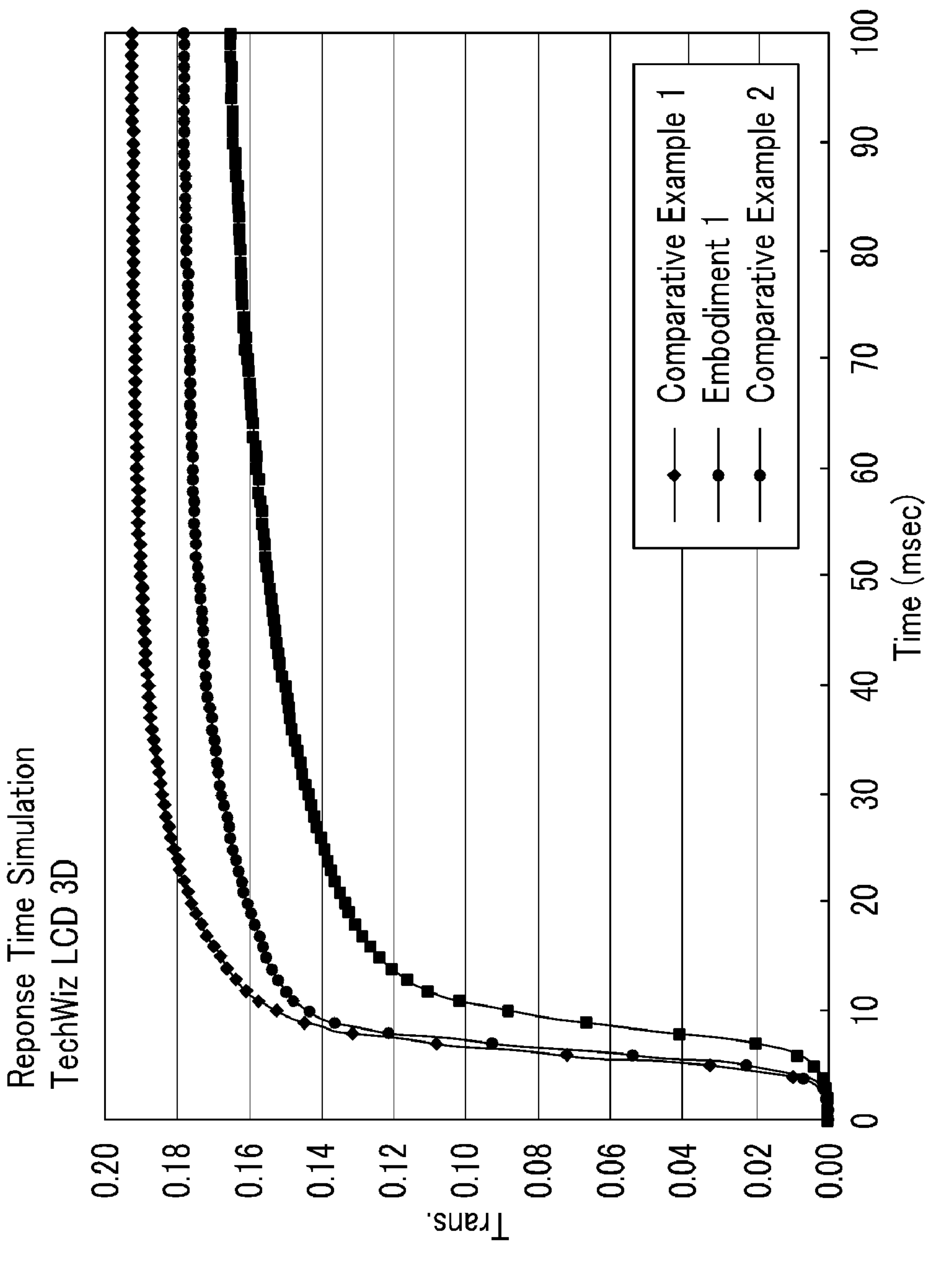
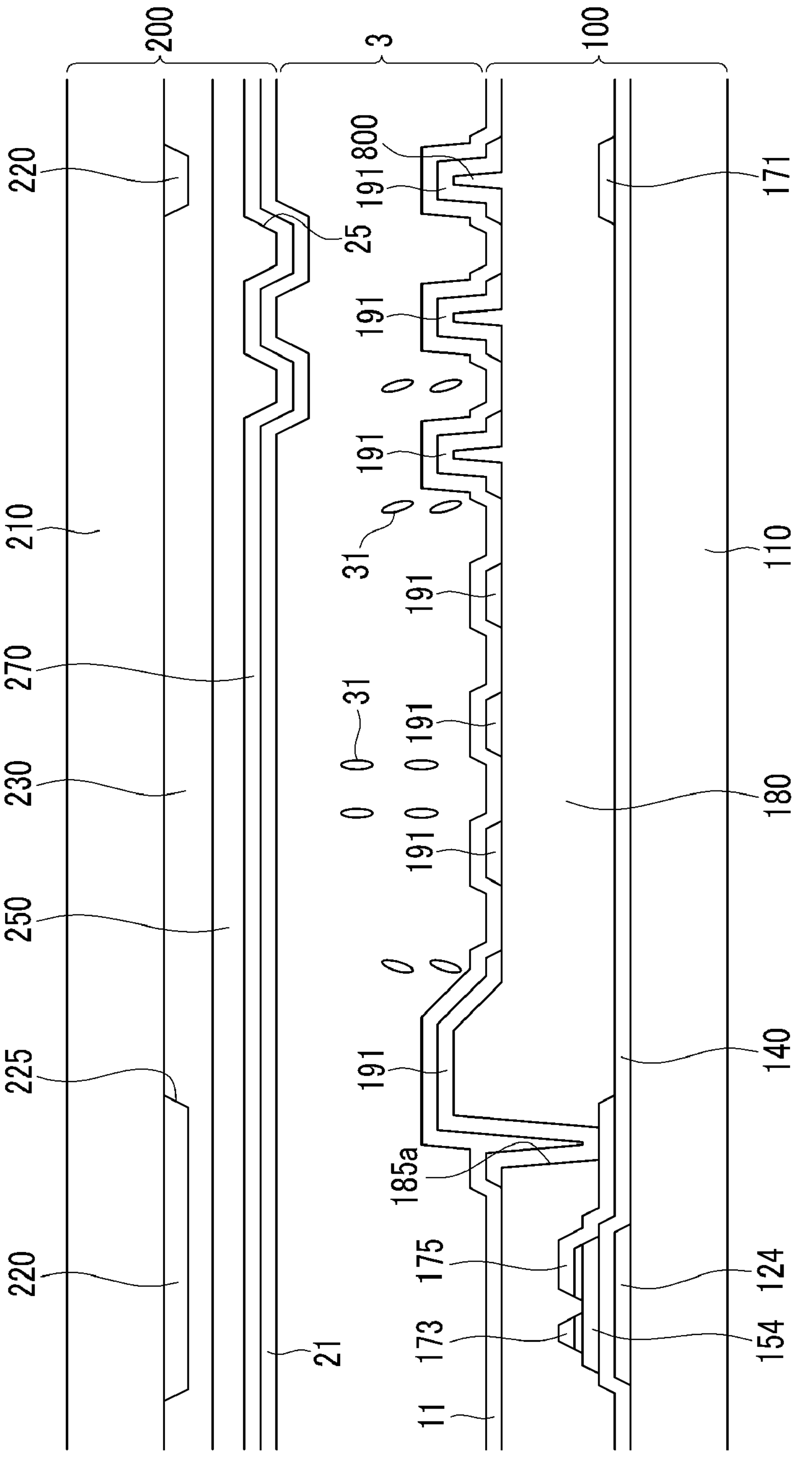

Reponse Time Simulation
TechWiz LCD 3D
Trans.
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
10
20
30
40
50
60
70
80
90
100
Time (msec)
Comparative Example 1
Embodiment 1
Comparative Example 2

FIG.7


200
3
100
220
210
270
230
250
225
220
25
21
800
191
191
191
31
191
31
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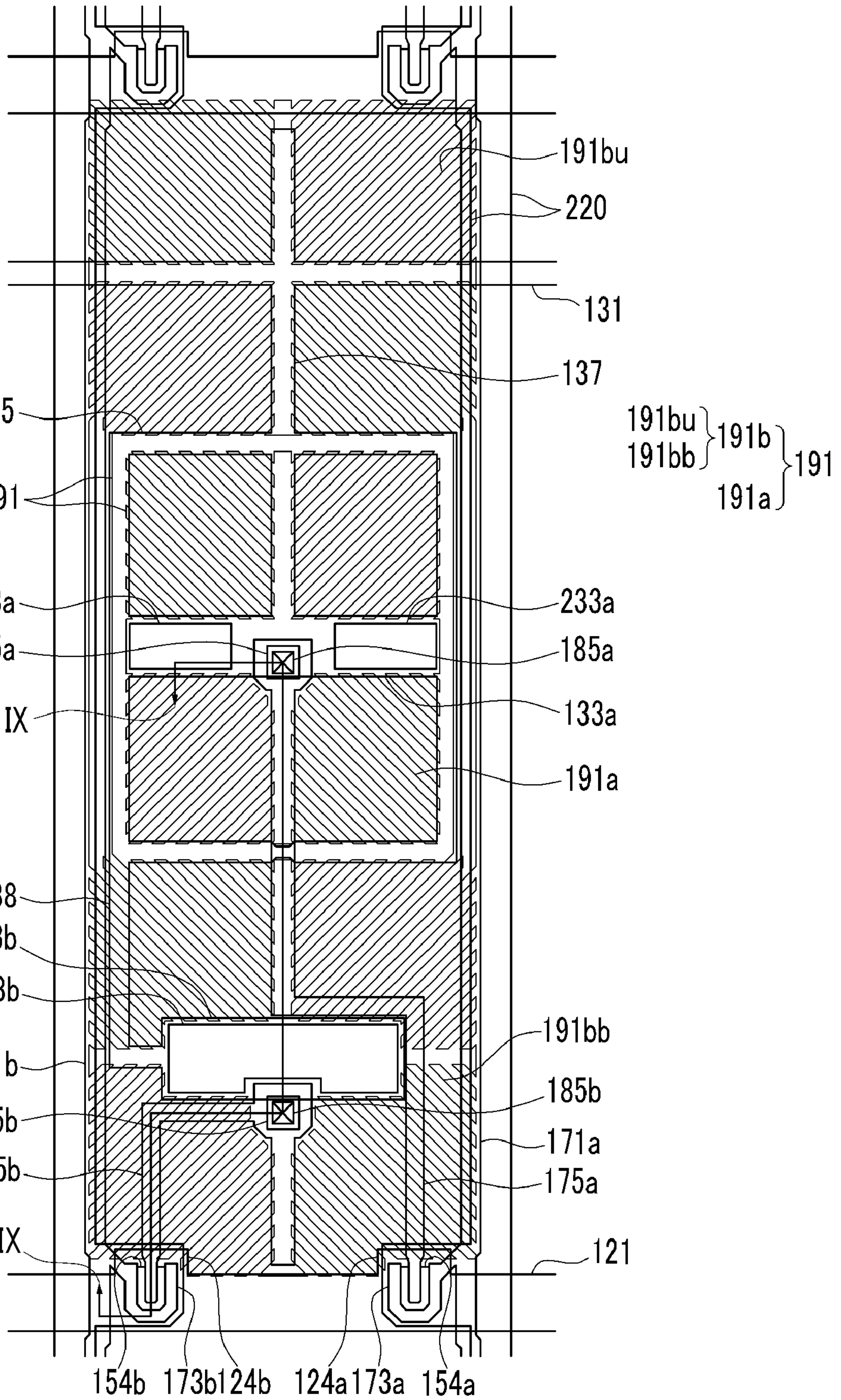
191
185a
175
173
11
171
110
180
140
124
154

# FIG.8



191bu
220
131
137
135
191bu
191bb
191b
191
191a
91
233a
233a
235a
185a
IX
133a
191a
138
133b
233b
191bb
171b
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235b
171a
175b
175a
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121
154b
173b
124b
124a
173a
154a

FIG.9

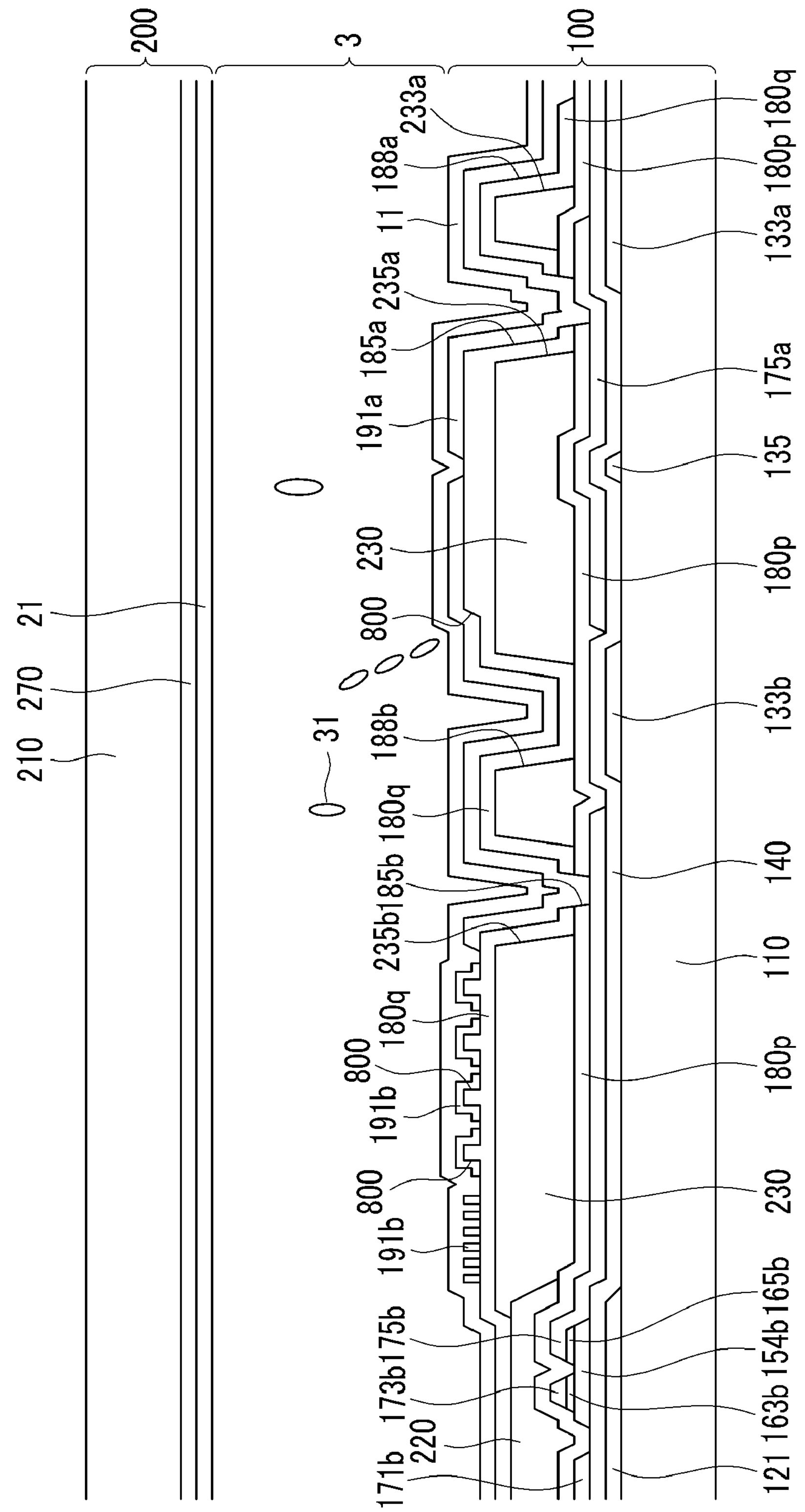
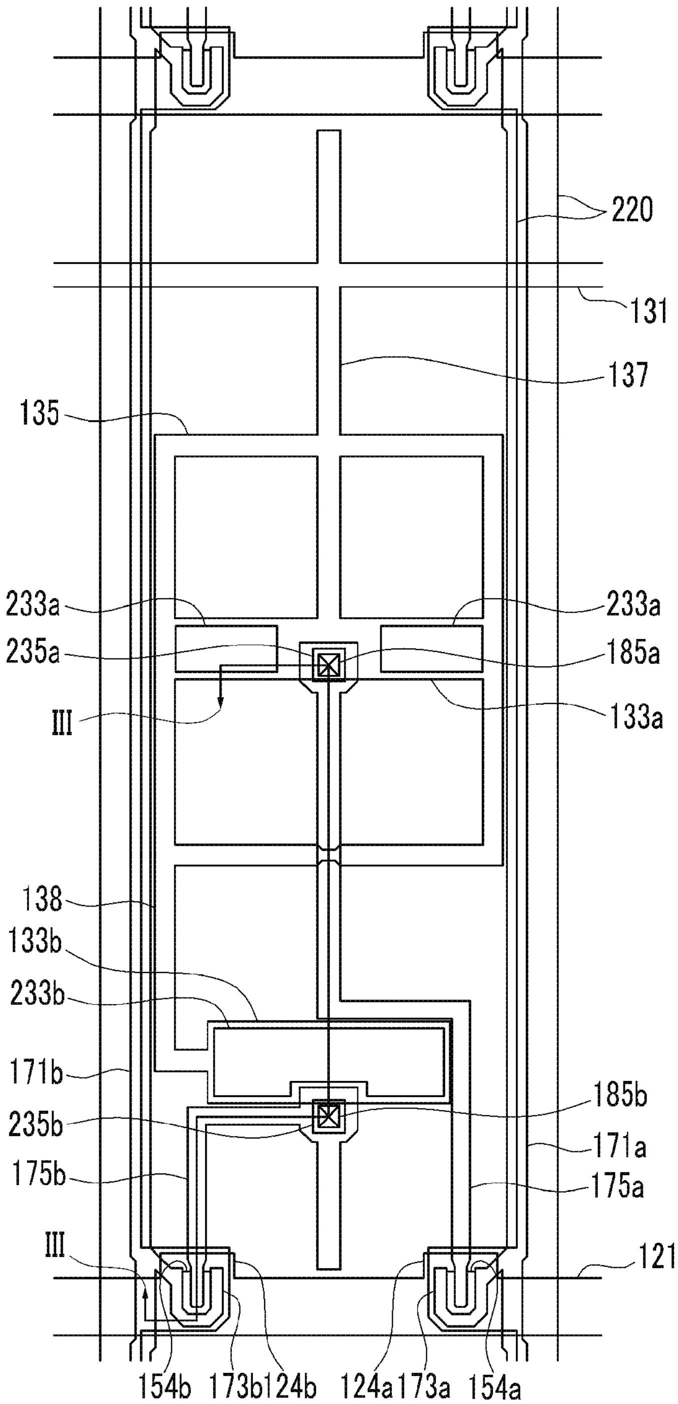

200
3
100
210
270
21
31
233a
188a
11
235a
185a
191a
230
800
188b
180q
185b
235b
191b
171b
220
173b
175b
180q
180p
133a
175a
135
133b
140
110
121
163b
154b
165b

FIG.10


220
131
137
135
233a
233a
235a
185a
III
133a
138
133b
233b
171b
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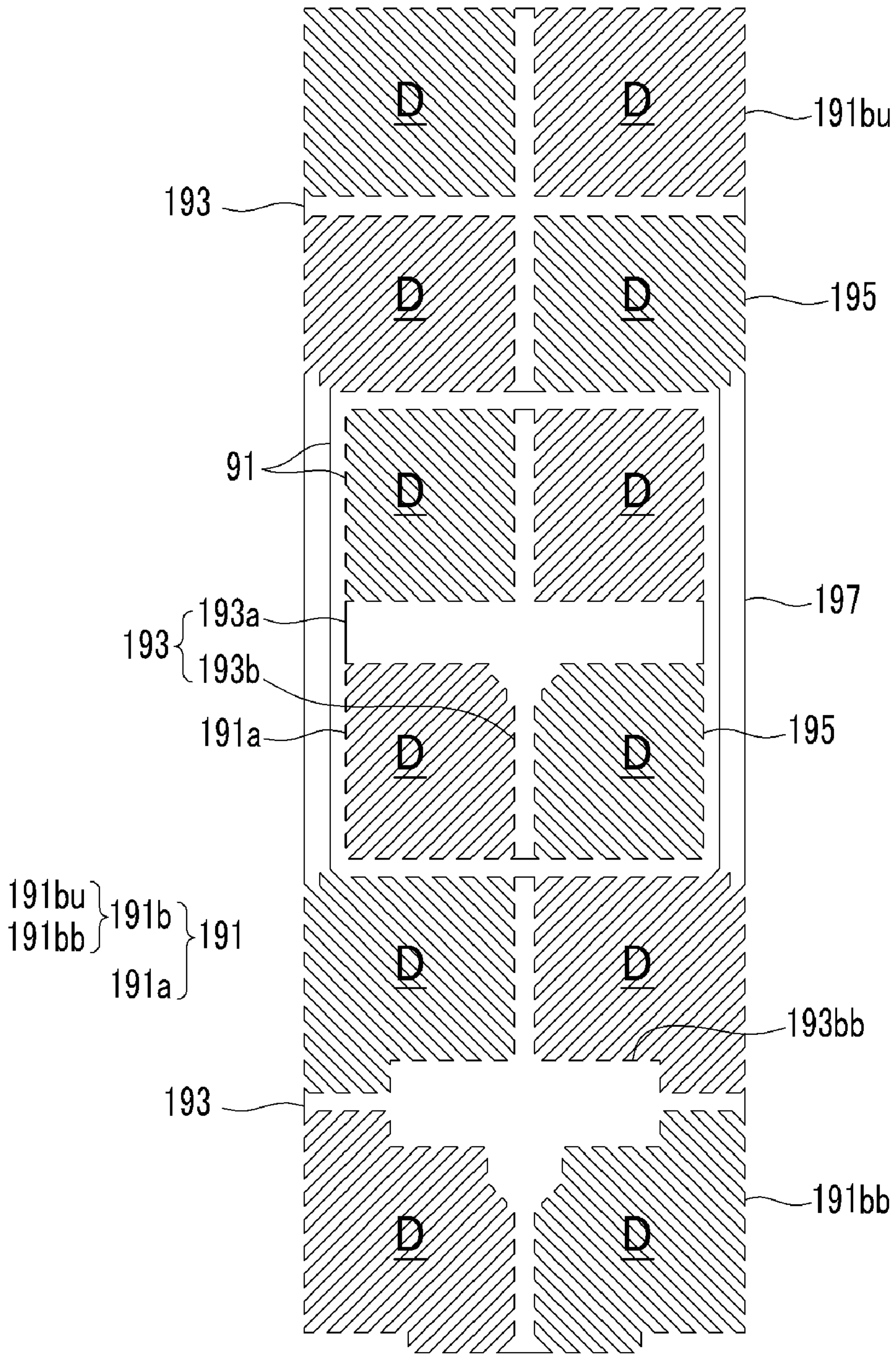
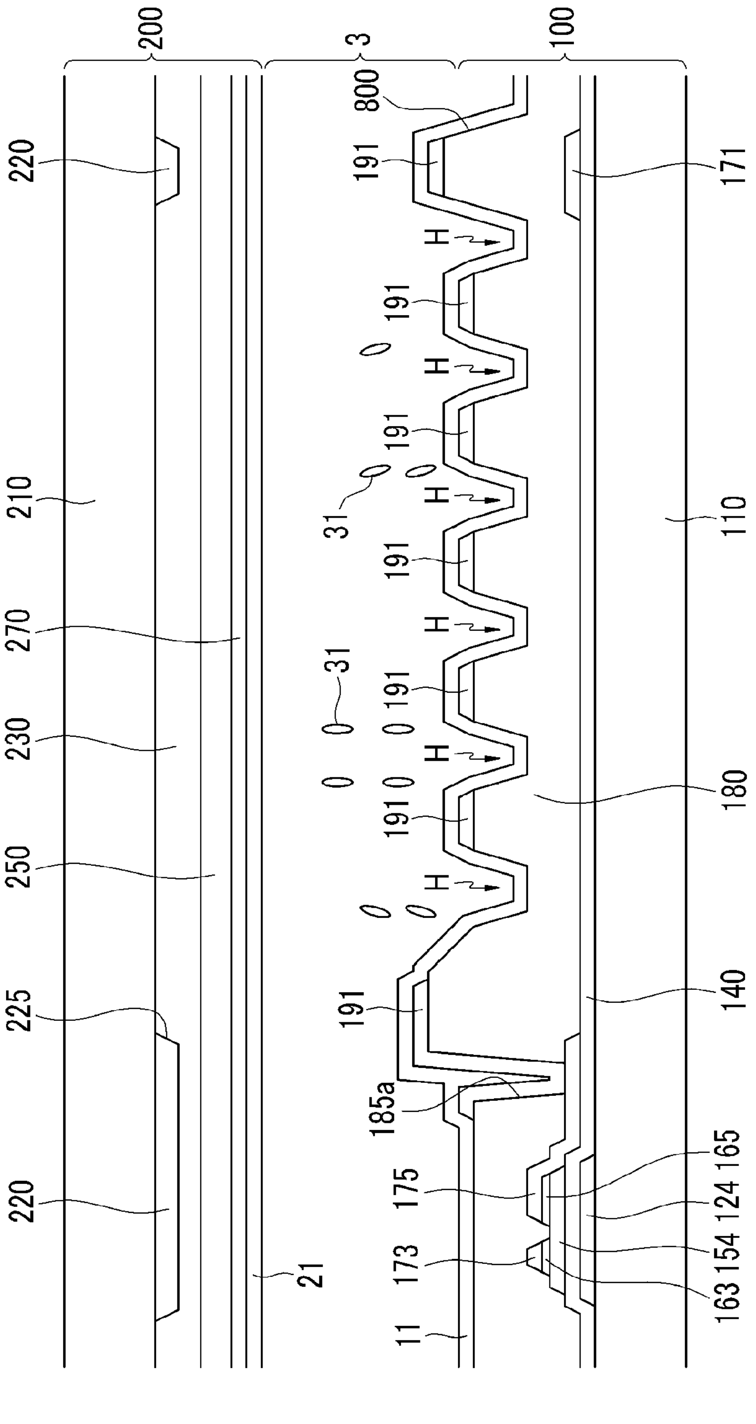
175a
III
121
154b
173b
124b
124a
173a
154a

# FIG.11



191bu
193
195
91
197
193
193a
193b
191a
195
191bu
191bb
191b
191
191a
193bb
193
191bb
D

FIG.12


200
3
100
800
220
191
171
H
31
210
110
270
230
250
180
225
140
185a
175
165
124
154
163
173
11
21

# LIQUID CRYSTAL DISPLAY AND METHOD THEREOF

[0001] This application claims priority to Korean Patent Application No. 10-2008-0088877, filed on Sep. 9, 2008, and all the benefits accruing therefrom under 35 U.S.C. §119, the contents of which in its entirety are herein incorporated by reference.

## BACKGROUND OF THE INVENTION

[0002] (a) Field of the Invention

[0003] The present invention relates to a liquid crystal display ("LCD") and method thereof. More particularly, the present invention relates to an LCD having an improved response speed and a method of improving response speed of the LCD.

[0004] (b) Description of the Related Art

[0005] A liquid crystal display ("LCD") is one of the most widely used flat panel displays ("FPD"), and it is composed of two display panels on which field generating electrodes are formed, and a liquid crystal layer interposed between the two display panels. A voltage is applied to the field generating electrodes to generate an electric field on the liquid crystal layer, and the orientation of liquid crystal molecules of the liquid crystal layer is determined and the polarization of incident light is controlled through the generated electric field to display an image.

[0006] Among the LCDs, a vertical alignment ("VA") mode LCD, which aligns LC molecules such that the long axes of the LC molecules are perpendicular to the panels in the absence of an electric field, has a high contrast ratio and wide reference viewing angle.

[0007] In the VA mode LCD, the wide reference viewing angle can be realized by forming a plurality of domains including LC molecules with different alignment directions in one pixel.

[0008] To form the plurality of domains in one pixel, there is a method of forming cutouts such as minute slits in the field generating electrodes or forming protrusions on the field generating electrodes. In this method, the plurality of domains may be formed by aligning the liquid crystal molecules perpendicular with respect to a fringe field generated between the edges of the cutout or protrusion, and the field generating electrodes facing the edges.

[0009] However, when the liquid crystal in the VA mode LCD is applied with the electric field of the perpendicular direction in the vertical aligned state, the inclination direction of the liquid crystal is random such that the response speed in which the LC molecules are aligned in one direction to form the domain is slow.

[0010] Accordingly, the liquid crystal may be pre-tilted to improve the response speed of the VA mode LCD.

## BRIEF SUMMARY OF THE INVENTION

[0011] It has been determined herein, according to the present invention, that the conventional VA mode liquid crystal display ("LCD") having pre-tilted liquid crystal to improve the response speed must increase the number of processes for improving the response speed.

[0012] The present invention improves response speed without additional processes.

[0013] The present invention also provides a method of improving response speed in an LCD without additional processes.

[0014] A liquid crystal display ("LCD") according to the present invention includes a first substrate and a second substrate facing each other, a plurality of pixel electrodes arranged in a matrix shape on the first substrate and each including a stem and a plurality of minute branches obliquely extending from the stem, a common electrode facing the plurality of pixel electrodes, and a liquid crystal layer interposed between the first substrate and the second substrate and including a plurality of liquid crystal molecules, wherein the pixel electrodes are classified into a plurality of sub-regions according to a length direction of the minute branches, and the minute branches are protruded at edges of the sub-regions.

[0015] The LCD may further include a passivation layer disposed between the first substrate and the pixel electrodes, and the passivation layer includes a first protrusion corresponding to the edges of the sub-regions.

[0016] One end of each of the minute branches may overlap the first protrusion, and the stem connected to the minute branches may overlap the first protrusion.

[0017] The passivation layer may be made of an organic material having a low dielectric ratio.

[0018] The LCD may further include a gate line disposed on the first substrate and disposed under the pixel electrode, a data line intersecting the gate line, and a thin film transistor ("TFT") connected to the gate line, the data line, and the pixel electrode, and the one end of each of the minute branches may overlap the data line.

[0019] The thickness of the first protrusion may be less than about 1/10 of the cell gap between an upper layer having the second substrate and a lower layer having the first substrate, and may preferably be less than about 0.5 μm.

[0020] The cross-section of the first protrusion may be trapezoidal.

[0021] The liquid crystal molecules close to the first protrusion among the liquid crystal molecules of the liquid crystal layer may be perpendicular to a side surface of the first protrusion, and liquid crystal molecules corresponding to a central region of the minute branches among the liquid crystal molecules of the liquid crystal layer may be perpendicular to the substrate.

[0022] The LCD may further include an overcoat formed between the common electrode and the second substrate, and the overcoat may include a second protrusion corresponding to an area between first protrusions.

[0023] The common electrode may form a convexo-concave surface according to the second protrusion.

[0024] The thickness of the second protrusion may be less than about 1/10 of the cell gap between an upper layer having the second substrate and a lower layer having the first substrate, and the thickness of the second protrusion may be less than about 0.5 μm.

[0025] The cross-section of the second protrusion may be trapezoidal.

[0026] The minute branches of neighboring sub-regions may be symmetrical with respect to the stem of the sub-regions, and the minute branches of two neighboring sub-regions may be orthogonal to each other.

[0027] In an alternative exemplary embodiment, a first groove may be disposed according to a length direction of the minute branches between the minute branches.

[0028] According to the present invention, the response speed of the LCD may be improved without additional processes.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0029] The above and other features and advantages of the present invention will become more apparent by describing exemplary embodiments thereof with reference to the accompanying drawings, in which:

[0030] FIG. **1** is a layout view of an exemplary liquid crystal display ("LCD") according to an exemplary embodiment of the present invention;

[0031] FIG. **2** is a cross-sectional view taken along line II-II of FIG. **1**;

[0032] FIG. **3** is a cross-sectional view taken along line III-III of FIG. **1**;

[0033] FIG. **4** is a graph showing transmittances according to response time of an exemplary LCD according to an exemplary embodiment of the present invention and an LCD without protrusions;

[0034] FIG. **5** is a graph showing an azimuth angle of a liquid crystal molecule in an exemplary LCD according to an exemplary embodiment of the present invention and an LCD according to a comparative example;

[0035] FIG. **6** is a graph showing response time and transmittance of a liquid crystal molecule in an exemplary LCD according to an exemplary embodiment of the present invention and an LCD according to a comparative example;

[0036] FIG. **7** is a cross-sectional view of an exemplary LCD according to another exemplary embodiment of the present invention, taken along line II-II of FIG. **1**;

[0037] FIG. **8** is a layout view of an exemplary LCD according to an exemplary embodiment of the present invention;

[0038] FIG. **9** is a cross-sectional view taken along line IX-IX of FIG. **8**;

[0039] FIG. **10** is a layout view of the exemplary LCD shown in FIG. **8** except for the pixel electrode;

[0040] FIG. **11** is a layout view of the exemplary pixel electrode in the exemplary LCD shown in FIG. **8**; and,

[0041] FIG. **12** is a cross-sectional view of an exemplary LCD according to another exemplary embodiment of the present invention, taken along line II-II of FIG. **1**.

## DETAILED DESCRIPTION OF THE INVENTION

[0042] The present invention will be described more fully hereinafter with reference to the accompanying drawings, in which exemplary embodiments of the invention are shown. As those skilled in the art would realize, the described embodiments may be modified in various different ways, all without departing from the spirit or scope of the present invention.

[0043] In the drawings, the thickness of layers, films, panels, regions, etc., are exaggerated for clarity. Like reference numerals designate like elements throughout the specification. It will be understood that when an element such as a layer, film, region, or substrate is referred to as being "on" another element, it can be directly on the other element or intervening elements may also be present. In contrast, when an element is referred to as being "directly on" another element, there are no intervening elements present.

[0044] It will be understood that, although the terms first, second, third etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms are only used to distinguish one element, component, region, layer or section from another element, component, region, layer or section. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the present invention.

[0045] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," or "includes" and/or "including" when used in this specification, specify the presence of stated features, regions, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, regions, integers, steps, operations, elements, components, and/or groups thereof.

[0046] Spatially relative terms, such as "beneath", "below", "lower", "above", "upper" and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the exemplary term "below" can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

[0047] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and the present disclosure, and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0048] Embodiments of the present invention are described herein with reference to cross section illustrations that are schematic illustrations of idealized embodiments of the present invention. As such, variations from the shapes of the illustrations as a result, for example, of manufacturing techniques and/or tolerances, are to be expected. Thus, embodiments of the present invention should not be construed as limited to the particular shapes of regions illustrated herein but are to include deviations in shapes that result, for example, from manufacturing. For example, a region illustrated or described as flat may, typically, have rough and/or nonlinear features. Moreover, sharp angles that are illustrated may be rounded. Thus, the regions illustrated in the figures are schematic in nature and their shapes are not intended to illustrate the precise shape of a region and are not intended to limit the scope of the present invention.

### First Exemplary Embodiment

[0049] A liquid crystal display ("LCD") according to an exemplary embodiment of the present invention will be described with reference to FIG. **1** to FIG. **3**.

[0050] FIG. **1** is a layout view of an exemplary LCD according to an exemplary embodiment of the present invention, FIG. **2** is a cross-sectional view taken along line II-II of FIG. **1**, and FIG. **3** is a cross-sectional view taken along line III-III of FIG. **1**.

[0051] Referring to FIG. **1** to FIG. **3**, an LCD according to an exemplary embodiment of the present invention includes a lower panel **100** and an upper panel **200** facing each other, and a liquid crystal layer **3** interposed between the two display panels **100** and **200**.

[0052] Firstly, the lower panel **100** will be described.

[0053] A plurality of gate lines **121** including a plurality of gate electrodes **124** protruding upward are formed, hereinafter disposed, on an insulating substrate **110**. The gate lines **121** transmit gate signals and are substantially extended in the transverse direction, such as a first direction.

[0054] A gate insulating layer **140** is disposed on the gate lines **121**, and a plurality of semiconductor islands **154** preferably made of amorphous or crystallized silicon are disposed on the gate insulating layer **140**.

[0055] A plurality of pairs of ohmic contacts **163** and **165** are disposed on the semiconductor islands **154**. The ohmic contacts **163** and **165** may include a material such as n+hydrogenated amorphous silicon ("a-Si") in which an n-type impurity is doped with a high concentration, or of silicide.

[0056] A plurality of data lines **171** and a plurality of drain electrodes **175** are disposed on the ohmic contacts **163** and **165** and the gate insulating layer **140**.

[0057] The data lines **171** transmit data signals, extend substantially in the longitudinal direction, a second direction substantially perpendicular to the first direction, and cross the gate lines **121**. Each data line **171** includes a plurality of source electrodes **173** extending toward the gate electrodes **124** and curved with a "U" shape.

[0058] One end of each drain electrode **175** is enclosed by a source electrode **173**, and the other end thereof has a wide area for connection with another layer.

[0059] A gate electrode **124**, a source electrode **173**, and a drain electrode **175** respectively form a thin film transistor ("TFT") along with a semiconductor island **154**, and a channel of the TFT is disposed on the semiconductor island **154** between the source electrode **173** and the drain electrode **175**.

[0060] The ohmic contacts **163** are interposed only between the underlying semiconductor islands **154**, and the overlying data lines **171** and drain electrodes **175**, and reduce contact resistance between them. The semiconductor islands **154** have a portion that is exposed without being covered by the data lines **171** and the drain electrodes **175**, and a portion between the source electrodes **173** and the drain electrodes **175**.

[0061] A passivation layer **180** preferably made of inorganic insulator or an organic insulator is disposed on the data lines **171**, the drain electrodes **175**, and the exposed semiconductor islands **154**. When the passivation layer **180** is made of the organic insulator, a lower layer may be made of a soft material having a low dielectric ratio and an upper layer may be made of a solid material having a higher dielectric ratio than that of the lower layer.

[0062] The passivation layer **180** has a plurality of contact holes **185** exposing the drain electrodes **175**. The passivation layer **180** includes protrusions **800** that are protruded compared with another portion of the passivation layer **180** and the protrusions **800** are integrated with the passivation layer **180**, however they may be formed with another layer.

[0063] The thickness of the protrusions **800** may be less than about 1/10 of the cell gap, and preferably less than about 0.5 μm. The cell gap is the distance between the upper panel **200** and the lower panel **100**. For example, when the cell gap is in the range of about 3.2 to about 4.0 μm, the thickness of the protrusions **800** is less than about 0.32 to about 0.4 μm. The protrusions **800** may have a trapezoidal cross-section.

[0064] When the passivation layer **180** includes the organic insulating material having the low dielectric ratio, a pixel electrode **191** that will be described later may overlap the data lines **171** such that the protrusions **800** are disposed to be overlapped with the data lines **171**. If the protrusions **800** are disposed on the data lines **171**, the passivation layer **180** is protruded by the data lines **171** such that the thickness of the protrusions **800** is increased by the thickness of the data lines **171**, thereby obtaining the same effects even if the thickness of the protrusions **800** is reduced by the thickness of the data lines **171**.

[0065] When integrally forming the protrusions **800**, as in an exemplary embodiment of the present invention, a photosensitive film pattern having different thicknesses depending on positions is disposed on an insulating layer for the passivation layer **180** by using halftone exposure using slits, and the passivation layer **180** may be formed by using the photosensitive film pattern as a mask. In an alternative exemplary embodiment the passivation layer **180** may be directly made of a photosensitive material, and halftone exposed and developed.

[0066] A plurality of pixel electrodes **191** preferably made of a transparent conductive material such as indium tin oxide ("ITO") or indium zinc oxide ("IZO"), or a reflective metal such as aluminum (Al), silver (Ag), chromium (Cr), or alloys thereof, are disposed on the passivation layer **180**.

[0067] The pixel electrodes **191** are connected to the drain electrodes **175** through the contact holes **185** and receive data voltages from the drain electrodes **175**.

[0068] The pixel electrodes **191** may have a quadrangular shape, and include a stem **193** and a plurality of minute branches **195**.

[0069] In detail, the stem **193** includes a transverse stem **193***a*, extending substantially in the first direction, and a longitudinal stem **193***b*, extending substantially in the second direction, crossing the pixel in the transverse and the longitudinal directions, respectively, and the transverse stem **193***a* and the longitudinal stem **193***b* cross each other. The pixel electrodes **191** are divided into a plurality of sub-regions D by the stem **193**.

[0070] The minute branches **195** are disposed in the sub-regions D, extend obliquely with respect to the transverse stem **193***a* and the longitudinal stem **193***b*, and form an angle of about 45 degrees with the gate line **121**.

[0071] The minute branches **195** of the neighboring sub-regions D are symmetrical with reference to the transverse stem **193***a* or the longitudinal stem **193***b*, and may be crossed.

[0072] The width of the minute branches **195** may be in the range of about 2.5 μm to about 5.0 μm, and the interval between the neighboring minute branches **195** in the sub-regions D may be in the range of about 2.5 μm to about 5.0 μm.

[0073] The protrusions **800** of the passivation layer **180** correspond to the edges of the sub-regions D, and the end portions of the minute branches **195** overlap the protrusions **800**. Thus, the end portions of the minute branches **195** protrude towards the upper panel **200**.

**[0074]** That is, the protrusions **800** overlap with the end portions of the stems **193** of the pixel electrode **191** and the minute branches **195** disposed on the edges of the sub-regions D. Therefore, while the pixel electrode **191** may be formed from a layer of the LCD having a substantially constant thickness, select portions of the pixel electrode **191** protrude towards the upper panel **200**.

**[0075]** An alignment layer **11** is disposed on the pixel electrode **191**.

**[0076]** Next, the upper panel **200** will be described.

**[0077]** A light blocking member **220** is disposed on a substrate **210**. The light blocking member **220** prevents light leakage between the pixel electrodes **191** and includes openings **225** defining the regions facing the pixel electrodes **191**.

**[0078]** A plurality of color filters **230** are disposed on the substrate **210** and the light blocking member **220**. The color filters **230** are mostly existent within the regions defined by the light blocking member **220**, however they may overlap the light blocking member **220**. The color filters **230** may longitudinally extend along the columns of pixel electrodes **191** in the vertical direction. Each of the color filters **230** may display one color in a set of colors, such as three primary colors, such as red, green, and blue.

**[0079]** An overcoat **250** is disposed on the color filter **230** and the light blocking member **220**, and a common electrode **270** preferably made of a transparent conductor such as ITO or IZO is disposed on the whole surface, or substantially an entire surface, of the overcoat **250**. In an alternative exemplary embodiment, the overcoat **250** may be omitted if necessary.

**[0080]** An alignment layer **21** is coated or otherwise disposed on the common electrode **270**.

**[0081]** The two alignment layers **11** and **21** may be vertical alignment layers. A polarizer (not shown) may be provided on the outer surface of the display panels **100** and **200**. The transmissive axes of two polarizers (not shown) are crossed and form an angle of about 45 degrees with the minute branches **195**.

**[0082]** The liquid crystal layer **3** between the lower panel **100** and the upper panel **200** has negative dielectric anisotropy, and may be oriented such that the major axes of the liquid crystal molecules **31** of the liquid crystal layer **3** are almost perpendicular to the surfaces of the two display panels **100** and **200** when no electric field is applied to the pixel electrodes **191** and common electrode **270**.

**[0083]** The pixel electrodes **191**, to which the data voltage is applied, generate an electric field together with the common electrode **270** of the upper panel **200** that receives the common voltage. Thus, liquid crystal molecules **31** of the liquid crystal layer **3** change directions so that the major axes thereof become perpendicular to the direction of the electric field in response to the electric field. The change degree of the polarization of the light that is incident to the liquid crystal layer **3** is changed according to the inclination degree of the liquid crystal molecules **31**, and this change of polarization appears as a change of transmittance by the polarizer, thereby displaying images on the LCD.

**[0084]** Here, the edges of the minute branches **195** distort the electric field to make the horizontal components perpendicular to the edges of the minute branches **195**, and the inclination direction of the liquid crystal molecules **31** is determined to be the direction determined by the horizontal components. Accordingly, the liquid crystal molecules **31** initially tend to incline in the direction perpendicular to the edges of the minute branches **195**. However, the directions of the horizontal components of the electric field by the neighboring minute branches **195** are opposite to each other and the intervals between the minute branches **195** are narrow such that the liquid crystal molecules **31** that tend to arrange in the opposite directions are tilted in the direction parallel to the length direction of the minute branches **195**.

**[0085]** Accordingly, if the liquid crystal molecules **31** are initially not pre-tilted in the length direction of the minute branches **195**, the liquid crystal molecules **31** are tilted in the length direction of the minute branches **195** through two steps.

**[0086]** However, in the present exemplary embodiment, the liquid crystal molecules **31** are already pre-tilted by the protrusions **800** such that the liquid crystal molecules **31** are not tilted through two steps, but are tilted in the direction parallel to the length direction of the minute branches **195** through one step.

**[0087]** That is, in the present exemplary embodiment, the liquid crystal molecules **31** are inclined to have the pre-tilt angle in the direction parallel to the minute branches **195** due to the side surface of the protrusions **800**. If the electric field is applied, the liquid crystal molecules **31** that are disposed on the end portions of the minute branches **195** start the alignment and are aligned parallel to the minute branches **195**. Here, the inclination direction of the liquid crystal molecules **31** is already determined by the pre-tilt such that they are inclined in the pre-tilt direction parallel to the length direction of the minute branches **195** through one step, not two steps. Accordingly, the response speed of the LCD is increased.

**[0088]** In an exemplary embodiment of the present invention, the length directions in which the minute branches **195** are extended in one pixel PX are all four directions, such as about 45 degrees, about −45 degrees, about −135 degrees, and about 135 degrees, such that the inclined directions of the liquid crystal molecules **31** are all four directions. Therefore, the viewing angle of the LCD is widened by varying the inclined directions of the liquid crystal molecules **31**.

**[0089]** These results may be confirmed with reference to graphs as described below.

**[0090]** FIG. **4** is a graph showing transmittances according to response time of an exemplary LCD according to an exemplary embodiment of the present invention and an LCD without protrusions **800**.

**[0091]** Referring to FIG. **4**, when the speed is 10 msec, the transmittance of the LCD according to an exemplary embodiment of the present invention (Embodiment 1) is about 0.15, and that of the conventional art is about 0.09. Also, when the speed is 10 msec, the transmittance of the present invention has a higher value than the case (the comparative example, identified as conventional structure) in which the protrusions **800** are not formed. Also, the time representing the value of the transmittance of about 1.0 is fast in the present invention compared with the conventional art. The case identified as Embodiment 2 will be described further below with respect to FIG. **7**.

**[0092]** Accordingly, in the LCD according to an exemplary embodiment of the present invention, the response speed is improved as well as the transmittance, compared with the comparative example.

**[0093]** FIG. **5** is a graph showing an azimuth angle of a liquid crystal molecule in an exemplary LCD according to an exemplary embodiment of the present invention and an exemplary LCD according to a comparative example.

**[0094]** Referring to FIG. **5**, an azimuth angle of liquid crystal molecules according to an exemplary embodiment of the present invention is mostly in the range of 130-135 degrees, parallel to the minute branches **195**, however an azimuth angle of the liquid crystal molecules of the LCD according to comparative example is in the range of 125-135 degrees, the deviation thereof is large, and the most thereof are at 130 degrees.

**[0095]** Accordingly, in an exemplary embodiment of the present invention, the liquid crystal molecules **31** are mostly aligned parallel to the minute branches **195**, thereby improving the transmittance.

**[0096]** FIG. **6** is a graph showing response time and transmittance of liquid crystal molecules in an exemplary LCD according to an exemplary embodiment of the present invention and an LCD according to a comparative example.

**[0097]** In FIG. **6**, Comparative Example 1 is a case in which the liquid crystal molecules are pre-tilted by using UV hardener as in an exemplary embodiment of the present invention, and Comparative Example 2 is a case in which UV hardener is not added and the liquid crystal molecules are not pre-tilted.

**[0098]** Referring to FIG. **6**, transmittance and response speed of an LCD according to an exemplary embodiment of the present invention are improved with respect to Comparative Example 2 such that the curve of the present invention is close to that of Comparative Example 1 as though the curve of the present invention smaller than that of Comparative Example 1.

**[0099]** That is, as an exemplary embodiment of the present invention, the protrusions overlapping with the edges of the pixel electrodes are formed for the liquid crystal molecules to have the pre-tilt angle such that transmittance and response speed that are improved compared with Comparative Example 2 may be obtained without the addition of the UV hardener used in Comparative Example 1.

**[0100]** Accordingly, the process for exposing the UV hardener is not necessary in the present invention, thereby simplifying the manufacturing process.

Second Exemplary Embodiment

**[0101]** FIG. **7** is a cross-sectional view of an exemplary LCD according to another exemplary embodiment of the present invention, taken along line II-II of FIG. **1**.

**[0102]** The layered structure of the LCD according to the present exemplary embodiment and the descriptions thereof are substantially the same as those of the previous exemplary embodiment shown in FIG. **1** to FIG. **3**, so description of the same elements is omitted and only different elements from those of the previous exemplary embodiment will be described in the current exemplary embodiment of the present invention. The lower panel **100** is the same as the lower panel **100** shown in FIG. **2**, such that only the upper panel **200** will be described.

**[0103]** In the upper panel **200** of FIG. **7**, a light blocking member **220** having openings **225** is disposed on a substrate **210**. Also, a plurality of color filters **230** are disposed on the substrate **210** and the light blocking member **220**.

**[0104]** An overcoat **250** is disposed on the color filters **230** and the light blocking member **220**, and a common electrode **270** made of the transparent conductor such as ITO and IZO is disposed on the whole surface, or substantially the whole surface, of the overcoat **250**. An alignment layer **21** is disposed on the common electrode **270**.

**[0105]** However, the overcoat **250** of FIG. **7** has protrusions **25** and the protrusions **25** correspond to the portions between the neighboring minute branches **195** of the lower panel **100**.

**[0106]** Referring to FIG. **4**, the transmittance and the response speed of the LCD according to an exemplary embodiment of the present invention (Exemplary Embodiment 2) is improved compared with the comparative example (conventional structure) such that the transmittance and the response speed may have almost the same value as that of the LCD according to the exemplary embodiment (Exemplary Embodiment 1) of FIG. **1**.

Third Exemplary Embodiment

**[0107]** FIG. **8** is a layout view of an exemplary LCD according to an exemplary embodiment of the present invention, FIG. **9** is a cross-sectional view taken along line IX-IX of FIG. **8**, FIG. **10** is a layout view of the exemplary LCD shown in FIG. **8** except for the pixel electrode, and FIG. **11** is a layout view of the exemplary pixel electrode in the exemplary LCD shown in FIG. **8**.

**[0108]** Referring to FIG. **8** to **11**, a plurality of gate lines **121** and a plurality of storage electrode lines are disposed on an insulating substrate **110**.

**[0109]** The gate lines **121** transmit gate signals and extend in a transverse direction, the first direction. Each gate line **121** includes a plurality of first and second gate electrodes **124***a* and **124***b* protruding upward.

**[0110]** The storage electrode lines include a stem **131** extending substantially parallel to the gate lines **121**, and a plurality of branches extended from the stem **131**. Each branch includes a longitudinal portion **137**, **138**, a hook-shaped portion **135**, a first storage electrode **133***a*, and a second storage electrode **133***b*.

**[0111]** The longitudinal portion **137** is extended upward and downward in the second direction from the stem **131** (hereinafter, an imaginary straight line of the direction that the longitudinal portion **137** is extended is referred as a "longitudinal central line"). The longitudinal portion **138** is extended downward from left or right of the stem **131**, and may extend downward from the hook-shaped portion **135**.

**[0112]** The hook-shaped portion **135** is almost rectangular, and the upper edge thereof vertically meets the longitudinal portion **137**.

**[0113]** The first storage electrode **133***a* is extended in a transverse direction from a central portion of the left edge of the hook-shaped portion **135** to a central portion of the right edge of the hook-shaped portion **135**, and has a wider width than the longitudinal portion **137** or the hook-shaped portion **135**. The first storage electrode **133***a* and the longitudinal portion **137** vertically meet each other, as shown in FIG. **10**, with the longitudinal portion **137** crossing the area defined by the hook-shaped portion **135** to meet the first storage electrode **133***a*.

**[0114]** The left edge of the hook-shaped portion **135** is extended downward to form longitudinal portion **138** and is curved in the right direction to form the second storage electrode **133***b*. The width of the second storage electrode **133***b* is expanded, as compared to a width of the longitudinal portion **138** or hook-shaped portion **135**, and is extended substantially parallel to the first storage electrode **133***a* in the transverse direction.

**[0115]** However, the shapes and arrangement of the storage electrode lines **131**, **133***a*, **133***b*, **135**, **137**, and **138** may be modified in various forms.

**[0116]** A gate insulating layer **140** is disposed on the gate lines **121** and the storage electrode lines **131**, **133***a*, **133***b*, **135**, **137**, and **138**, and a plurality of semiconductors **154***a* and **154***b* preferably made of amorphous or crystallized silicon are disposed on the gate insulating layer **140**.

**[0117]** A pair of ohmic contacts **163***b* and **165***b* are disposed on the second semiconductor **154***b*, and a pair of data lines **171***a* and **171***b* and a plurality of first and second drain electrodes **175***a* and **175***b* are disposed on the ohmic contacts **163***b* and **165***b*, and on the gate insulating layer **140**. Although not shown, a pair of ohmic contacts may also be disposed on the first semiconductor **154***a*.

**[0118]** The data lines **171***a* and **171***b* transmit data signals, extend substantially in the longitudinal direction, the second direction, and cross the gate lines **121** and the stem **131** of the storage electrode lines. Each data line **171***a*/**171***b* includes a plurality of first/second source electrodes **173***a*/**173***b* extending toward the first/second gate electrodes **124***a*/**124***b* and may be curved with a "U" shape, and the first/second source electrodes **173***a*/**173***b* are opposite to the first/second drain electrodes **175***a*/**175***b* with respect to the first/second gate electrodes **124***a*/**124***b*.

**[0119]** In an exemplary embodiment, each first drain electrode **175***a* starts from one end enclosed by the first source electrode **173***a*, extends upward, curves in the left direction according to the upper edge of the second storage electrode **133***b*, and again extends upward near the longitudinal central line to form the other end of the first drain electrode **175***a*. The other end of the first drain electrode **175***a* is extended to where the first storage electrode **133***a* is disposed, and has a wide area for connection with another layer.

**[0120]** Each second drain electrode **175***b* starts from one end enclosed by the second source electrode **173***b*, extends upward to the second storage electrode **133***b*, curves in the right direction, extends according to the lower edge of the second storage electrode **133***b*, expands with a wide area near the longitudinal central line, and again extends downward.

**[0121]** While a particular arrangement has been shown and described, the shapes and arrangement of the first and second drain electrodes **175***a* and **175***b* and the data lines **171***a* and **171***b* may be modified in various forms.

**[0122]** A first/second gate electrode **124***a*/**124***b*, a first/second source electrode **173***a*/**173***b*, and a first/second drain electrode **175***a*/**175***b* respectively form a first/second TFT along with a first/second semiconductor **154***a*/**154***b*, and a channel of the first/second TFT is formed on the first/second semiconductor **154***a*/**154***b* between the first/second source electrode **173***a*/**173***b* and the first/second drain electrode **175***a*/**175***b*.

**[0123]** A lower passivation layer **180***p* preferably made of silicon nitride or silicon oxide is disposed on the data lines **171***a* and **171***b*, the drain electrodes **175***a* and **175***b*, and the exposed portions of the semiconductors **154***a* and **154***b*.

**[0124]** Light blocking members **220** may be disposed on the lower passivation layer **180***p* in a region of the first/second TFTs and along the first/second data lines **171***a*/**171***b*, the gate lines **121**, etc. A plurality of color filters **230** are disposed on the lower passivation layer **180***p*. The color filters **230** are mostly formed in a region surrounded by the light blocking members **220**. The color filters **230** have a plurality of holes **235***a* and **235***b* disposed on the first and second drain electrodes **175***a* and **175***b*, and a plurality of openings **233***a* and **233***b* disposed on the first and second storage electrodes **133***a* and **133***b*. The openings **233***a* and **233***b* reduce the thickness of the dielectric material forming the storage capacitors Csta and Cstb such that the storage capacitance may be increased.

**[0125]** Here, the lower passivation layer **180***p* may prevent the pigments of the color filter **230** from flowing into the exposed semiconductors **154***a* and **154***b*.

**[0126]** An upper passivation layer **180***q* is disposed on the color filters **230**. The upper passivation layer **180***q* may be made of an inorganic insulating material such as silicon nitride or silicon oxide, and prevents the color filters **230** from lifting and suppresses the contamination of the liquid crystal layer **3** by an organic material such as a solvent flowing from the color filters **230** such that defects such as an afterimage that may be generated during driving may be prevented.

**[0127]** The upper passivation layer **180***q* includes protrusions **800** as in the first exemplary embodiment, and the protrusions **800** may be formed into one body with the upper passivation layer **180***q*, or may be provided as an additional layer.

**[0128]** In an alternative exemplary embodiment, at least one of the light blocking members **220** and the color filters **230** may be disposed on the upper panel **200** as in the first embodiment, and one of the lower passivation layer **180***p* and the upper passivation layer **180***q* of the lower panel **100** may be omitted in this case.

**[0129]** When the upper passivation layer **180***q* is not formed, the protrusions **800** may be formed by using the color filters **230**.

**[0130]** The upper passivation layer **180***q* and the lower passivation layer **180***p* have a plurality of contact holes **185***a* and **185***b* respectively exposing the first and second drain electrodes **175***a* and **175***b*.

**[0131]** A plurality of pixel electrodes **191** are disposed on the upper passivation layer **180***q*, and the above-described color filters **230** may be extended according to a column of the pixel electrodes **191**.

**[0132]** Referring to FIG. **8**, and with further reference to FIG. **11**, each pixel electrode **191** includes the first and second subpixel electrodes **191***a* and **191***b* that are separated from each other with a gap **91** of a quadrangular belt shape therebetween. The first and second subpixel electrodes **191***a* and **191***b* are respectively included in a basic electrode with pixel electrode **191** as shown in FIG. **1**, or at least one modification thereof. Hereafter, pixel electrode **191** shown in FIG. **1** will be the basic electrode for convenience

**[0133]** Again, referring to FIG. **8** and FIG. **9**, as well as FIG. **11**, the first subpixel electrode **191***a* includes one basic electrode. The transverse stem **193** of the basic electrode forming the first subpixel electrode **191***a* expands downward and upward to form a first expansion **193***a*, and the first expansion **193***a* overlaps the first storage electrode **133***a*. Also, the protrusion that protrudes downward for easy contact with the first drain electrode **175***a* is formed in the center of the downward edge of the first expansion **193***a*. A longitudinal portion **193***b* may extend downwardly and upwardly from the first expansion **193***a* such that the first sub pixel electrode **191***a* is substantially divided into four quadrants.

**[0134]** The second subpixel electrode **191***b* includes an upper electrode **191***bu* and a lower electrode **191***bb*, and the upper electrode **191***bu* and the lower electrode **191***bb* respectively include one basic electrode. The upper electrode **191***bu* and the lower electrode **191***bb* are connected to each other through two left and right connections **197**.

**[0135]** The second subpixel electrode **191***b* encloses the first subpixel electrode **191***a* with the gap **91** interposed therebetween. A portion of the center of the transverse stem **193** of the lower electrode **191*bb*** extends upward and downward to form a second expansion **193*bb*** overlapping the second storage electrode **133*b***. Also, the protrusion that protrudes downward for easy contact with the second drain electrode **175*b*** is formed in the center of the downward edge of the second expansion **193*bb***. Longitudinal portions may extend upwardly and downwardly from the transverse stems **193** in the upper electrode **191*bu*** and lower electrode **191*bb*** such that each of the upper electrode **191*bu*** and lower electrode **191*bb*** are substantially divided into four quadrants.

**[0136]** The area of the second subpixel electrode **191*b*** may be about 1.0 to about 2.2 times the area of the first subpixel electrode **191*a***.

**[0137]** The end portions of the minute branches **195** disposed on the sub-regions D and the stem **193** are protruded towards the upper panel **200** by the protrusions **800** provided thereunder as compared with other portions of the minute branches **195** that do not overlap protrusions **800**.

**[0138]** Each first/second subpixel electrode **191*a*/191*b*** is physically and electrically connected to the first/second drain electrode **175*a*/175*b*** through the contact hole **185*a*/185*b***.

**[0139]** An alignment layer **11** is disposed on the pixel electrode **191**.

**[0140]** Next, the upper panel **200** will be described.

**[0141]** A common electrode **270** is disposed on an insulating substrate **210**, and an alignment layer **21** is disposed thereon. Each of the alignment layers **11** and **21** may be a vertical alignment layer.

**[0142]** Finally, polarizers (not shown) may be provided on the outer surface of the display panels **100** and **200**.

**[0143]** The first/second subpixel electrode **191*a*/191*b*** and the common electrode **270** form the liquid crystal capacitor to maintain an applied voltage even after the TFT is turned off. Also, the first and second storage electrodes **133*a*** and **133*b*** of the storage electrode line **131** respectively overlap with the first and second subpixel electrodes **191*a*** and **191*b*** in the openings **188*a*** and **188*b*** to form the storage capacitors Csta and Cstb.

**[0144]** The hook-shaped portion **135** of the storage electrode line **131** overlaps the gap **91** of the pixel electrode **191** such that it functions as a shielding member for blocking light leakage between the first subpixel electrode **191*a*** and the second subpixel electrode **191*b***. The hook-shaped portion **135** disposed between the data lines **171*a*** and **171*b***, and the first subpixel electrode **191*a***, prevents crosstalk to thereby reduce degradation of display quality.

**[0145]** The first subpixel electrode **191*a*** and the second subpixel electrode **191*b*** may be applied with different data voltages through the different data lines **171*a*** and **171*b***, and the voltage of the first subpixel electrode **191*a*** having the relatively small area may be higher than the voltage of the second subpixel electrode **191*b*** having the relatively large area.

**[0146]** In this way, if the voltages of the first subpixel electrode **191*a*** and the second subpixel electrode **191*b*** are different from each other, the voltage applied to the first liquid crystal capacitor Clca formed between the first subpixel electrode **191*a*** and the common electrode **270** and the voltage applied to the second liquid crystal capacitor Clcb formed between the second subpixel electrode **191*b*** and the common electrode **270** are different from each other such that the declination angle of the liquid crystal molecules **31** of the subpixels PXa and PXb are different from each other, and as a result the luminance of the two subpixels PXa and PXb become different. Accordingly, if the voltages of the first and second liquid crystal capacitors Clca and Clcb are appropriately controlled, the images shown at the side may be approximate to the image shown at the front, that is to say, the gamma curve of the side may be approximately close to the gamma curve of the front, thereby improving the side visibility.

## Fourth Exemplary Embodiment

**[0147]** FIG. **12** is a cross-sectional view of an exemplary LCD according to another exemplary embodiment of the present invention, taken along line II-II of FIG. **1**.

**[0148]** The layered structure of the LCD according to the present exemplary embodiment and the descriptions thereof are substantially the same as those of the previous exemplary embodiment shown in FIG. **1** to FIG. **3**, so descriptions of the same elements are omitted and only different elements from those of the previous exemplary embodiment will be described in the current exemplary embodiment of the present invention. The upper panel **200** is the same as the upper panel **200** shown in FIG. **2**, such that only the lower panel **100** will be described.

**[0149]** In the lower panel **100** of FIG. **12**, a gate line having a gate electrode **124** is disposed on a substrate **110**, and a gate insulating layer **140** is disposed on the gate electrode **124**. A semiconductor **154** and ohmic contacts **163** and **165** are disposed on the gate insulating layer **140**, and a data line **171** having a source electrode **173** overlapping the ohmic contacts **163** and **165**, and a drain electrode **175** are disposed on the semiconductor **154**, the ohmic contacts **163** and **165**, and the gate insulating layer **140**.

**[0150]** A passivation layer **180** is disposed on the data line **171** and the drain electrode **175**, and a pixel electrode **191** and an alignment layer **11** are disposed on the passivation layer **180**.

**[0151]** However, the passivation layer **180** shown in FIG. **12** includes grooves H at which the passivation layer **180** between the minute branches **195** is removed according to the minute branches **195**. Here, the depth of the grooves H is less than about 1/10 of the cell gap, and the depth of the grooves may be about 0.5 μm.

**[0152]** In an exemplary embodiment, the grooves H may be formed when forming the contact holes **185*a***. In an alternative exemplary embodiment, the grooves H may be formed by etching the passivation layer **180** by using the pixel electrode **191** or the photosensitive pattern for the pixel electrode **191** as a mask after forming the pixel electrode **191**.

**[0153]** A portion of the passivation layer **180** overlapping the data line **171** may be protruded from another portion of the data line **171**.

**[0154]** The liquid crystal molecules **31** are pre-tilted according to the grooves H through the whole substrate, thereby increasing the response speed of the liquid crystal molecules **31**.

**[0155]** Also, the LCD of FIG. **12** may include the protrusions of the upper panel like the second exemplary embodiment shown in FIG. **7**. In an alternative exemplary embodiment, the upper panel **200** may also include grooves, such as grooves within the overcoat **250**, and the protrusion may be formed according to the grooves.

**[0156]** While this invention has been described in connection with what is presently considered to be practical exemplary embodiments, it is to be understood that the invention is not limited to the disclosed embodiments, but, on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

What is claimed is:

**1**. A liquid crystal display comprising:

a first substrate and a second substrate facing each other;

a plurality of pixel electrodes arranged in a matrix shape on the first substrate and each including a stem and a plurality of minute branches obliquely extending from the stem;

a common electrode facing the plurality of pixel electrodes; and

a liquid crystal layer interposed between the first substrate and the second substrate and including a plurality of liquid crystal molecules,

wherein the pixel electrodes are classified into a plurality of sub-regions according to a length direction of the minute branches, and the minute branches are protruded at edges of the sub-regions.

**2**. The liquid crystal display of claim **1**, further comprising

a passivation layer disposed between the first substrate and the pixel electrodes,

wherein the passivation layer includes a first protrusion corresponding to the edges of the sub-regions.

**3**. The liquid crystal display of claim **2**, wherein

one end of the minute branches overlaps the first protrusion.

**4**. The liquid crystal display of claim **3**, wherein

the passivation layer is made of an organic material having a low dielectric ratio.

**5**. The liquid crystal display of claim **4**, further comprising:

a gate line disposed on the first substrate and disposed under the pixel electrode;

a data line intersecting the gate line; and

a thin film transistor connected to the gate line, the data line, and the pixel electrode,

wherein the one end of the minute branches overlaps the data line.

**6**. The liquid crystal display of claim **3**, wherein

the stem connected to the minute branches overlaps the first protrusion.

**7**. The liquid crystal display of claim **2**, wherein

a thickness of the first protrusion is less than about 1/10 of a cell gap between an upper layer having the second substrate and a lower layer having the first substrate.

**8**. The liquid crystal display of claim **7**, wherein

the thickness of the first protrusion is substantially 0.5 μm.

**9**. The liquid crystal display of claim **2**, wherein

a cross-section of the first protrusion is trapezoidal.

**10**. The liquid crystal display of claim **9**, wherein:

liquid crystal molecules close to the first protrusion among liquid crystal molecules of the liquid crystal layer are perpendicular to a side surface of the first protrusion.

**11**. The liquid crystal display of claim **10**, wherein

liquid crystal molecules corresponding to a central region of the minute branches among the liquid crystal molecules of the liquid crystal layer are perpendicular to the first substrate.

**12**. The liquid crystal display of claim **2**, further comprising

an overcoat disposed between the common electrode and the second substrate,

wherein the overcoat includes a second protrusion corresponding to an area between first protrusions.

**13**. The liquid crystal display of claim **12**, wherein

the common electrode forms a convexo-concave surface according to the second protrusion.

**14**. The liquid crystal display of claim **13**, wherein

a thickness of the second protrusion is less than about 1/10 of a cell gap between an upper layer having the second substrate and a lower layer having the first substrate.

**15**. The liquid crystal display of claim **14**, wherein

the thickness of the second protrusion is less than about 0.5 μm.

**16**. The liquid crystal display of claim **12**, wherein

a cross-section of the second protrusion is trapezoidal.

**17**. The liquid crystal display of claim **1**, wherein

the minute branches of neighboring sub-regions are symmetrical with respect to the stem of the sub-regions.

**18**. The liquid crystal display of claim **17**, wherein

the minute branches of two neighboring sub-regions are orthogonal to each other.

**19**. The liquid crystal display of claim **1**, wherein the minute branches protrude towards the second substrate at the edges of the sub-regions.

**20**. The liquid crystal display of claim **1**, wherein a layer of the liquid crystal display including the pixel electrodes has a substantially constant thickness.

**21**. A liquid crystal display comprising:

a first substrate and a second substrate facing each other;

a plurality of pixel electrodes arranged in a matrix shape on the first substrate and including a stem and a plurality of minute branches obliquely extending from the stem;

a common electrode facing the plurality of pixel electrodes; and

a liquid crystal layer interposed between the first substrate and the second substrate and including a plurality of liquid crystal molecules,

wherein the pixel electrodes are classified into a plurality of sub-regions according to a length direction of the minute branches, and a first groove is disposed according to the length direction of the minute branches between the minute branches.

**22**. The liquid crystal display of claim **21**, further comprising

a passivation layer disposed between the first substrate and the pixel electrodes,

wherein the first groove is formed in the passivation layer.

**23**. The liquid crystal display of claim **22**, further comprising

an overcoat disposed between the common electrode and the second substrate,

wherein the overcoat includes a second groove corresponding to an area between first grooves.

**24**. The liquid crystal display of claim **22**, wherein

the passivation layer is made of an organic material having a low dielectric ratio.

**25**. The liquid crystal display of claim **22**, wherein

a depth of the groove is less than about 1/10 of a cell gap between an upper layer having the second substrate and a lower layer having the first substrate.

**26**. The liquid crystal display of claim **25**, wherein

the depth of the groove is substantially 0.5 μm.

**27**. A method of improving response speed of a liquid crystal display, the method comprising:

arranging a plurality of pixel electrodes in a matrix shape on a first substrate of the liquid crystal display, each pixel electrode including a stem and a plurality of minute branches obliquely extending from the stem, the pixel electrodes classified into a plurality of sub-regions according to a length direction of the minute branches;

interposing a liquid crystal layer between the first substrate and a second substrate of the liquid crystal display; and,

protruding the minute branches at edges of the sub-regions towards the second substrate.

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摘要(译)

液晶显示器（“LCD”）包括彼此面对的第一和第二基板，在第一基板上以矩阵形状排列的多个像素电极，包括杆和从杆倾斜延伸的多个微小分支，共同的电极面对多个像素电极，液晶层夹在第一基板和第二基板之间并包括多个液晶分子，其中像素电极根据长度方向分为多个子区域分支分支和分支分支在子区域的边缘突出。