US 20010004277A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2001/0004277 A1**

Koma (43) **Pub. Date: Jun. 21, 2001**

(54) **LIQUID CRYSTAL DISPLAY INCLUDING A VERTICALLY ALIGNED LIQUID CRYSTAL LAYER DISPOSED BETWEEN PIXEL ELECTRODES AND A COMMON ELECTRODE**

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(21) Appl. No.: **09/768,371**

(22) Filed: **Jan. 23, 2001**

Related U.S. Application Data

(62) Division of application No. 09/162,984, filed on Sep. 29, 1998, now Pat. No. 6,229,589.

(30) **Foreign Application Priority Data**

Oct. 1, 1997 (JP) .... HEI 9-268973

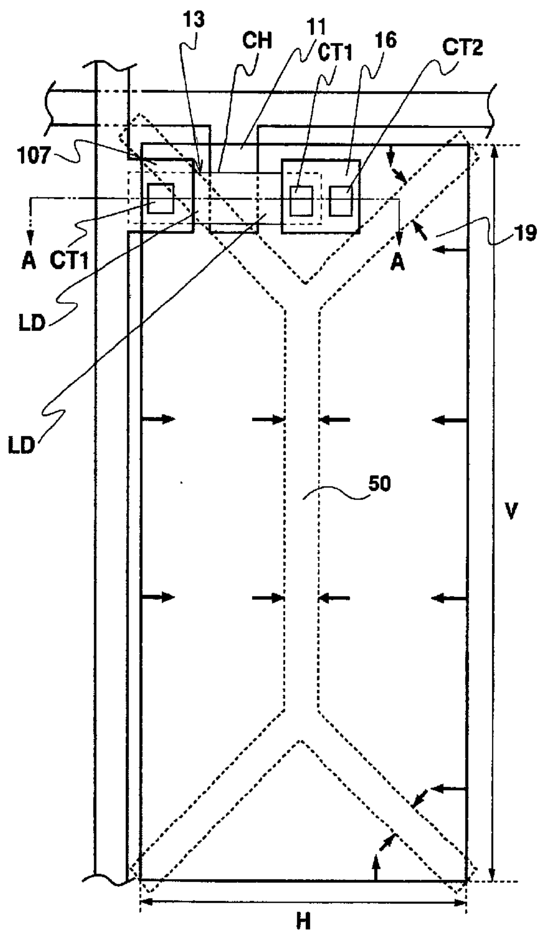
Publication Classification

(51) **Int. Cl.**[7] **G02F 1/1343**

(52) **U.S. Cl.** **349/143**; 349/139

(57) **ABSTRACT**

A vertically aligned type liquid crystal display includes a liquid crystal layer disposed between a pixel electrode and a common electrode and containing vertically aligned liquid crystal molecules, the orientation of the liquid crystal molecules being controlled by electric field. An orientation control window is formed in the common electrode located opposite to the pixel electrode and an aspect ration, i.e., a vertical to horizontal length ratio of the pixel electrode is set to at least 2. Alternatively, the pixel electrode is partitioned into at least two electrode regions that each region represents a divided pixel electrode. An orientation control window is formed in the common electrode so as to correspond to each divided pixel electrode, an aspect ratio of each divided pixel electrode is set to at least 2. As such, the influence at the edge sections of the pixel electrode is reduced, viewing angle characteristic and transmittance are improved, and average response time is shortened.



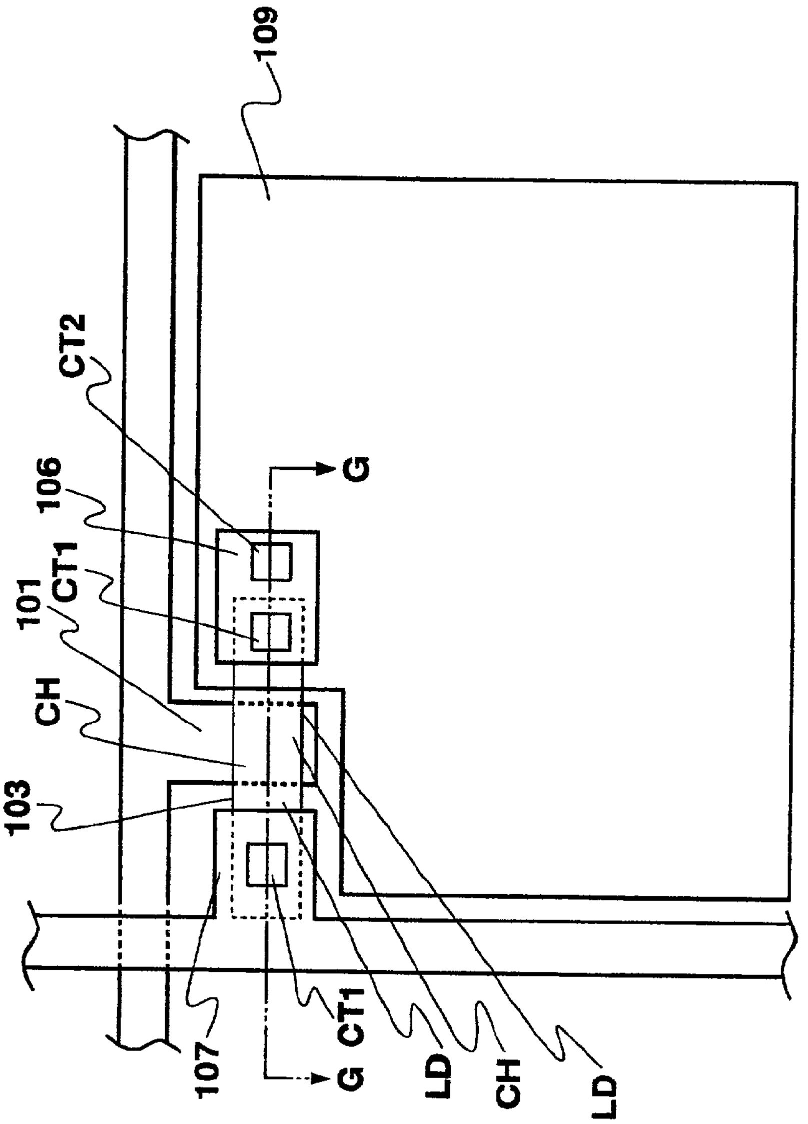


Fig. 1 PRIOR ART

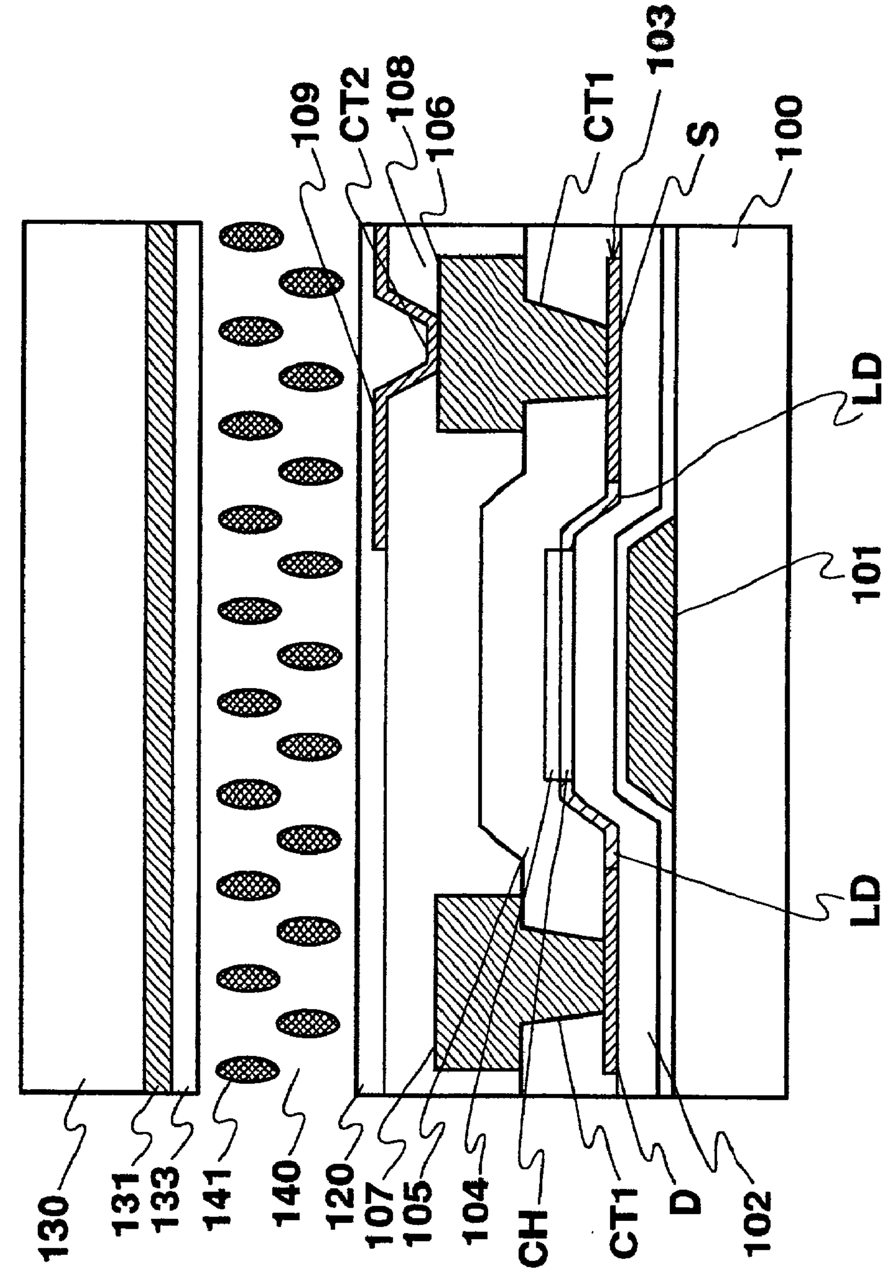


Fig. 2 PRIOR ART

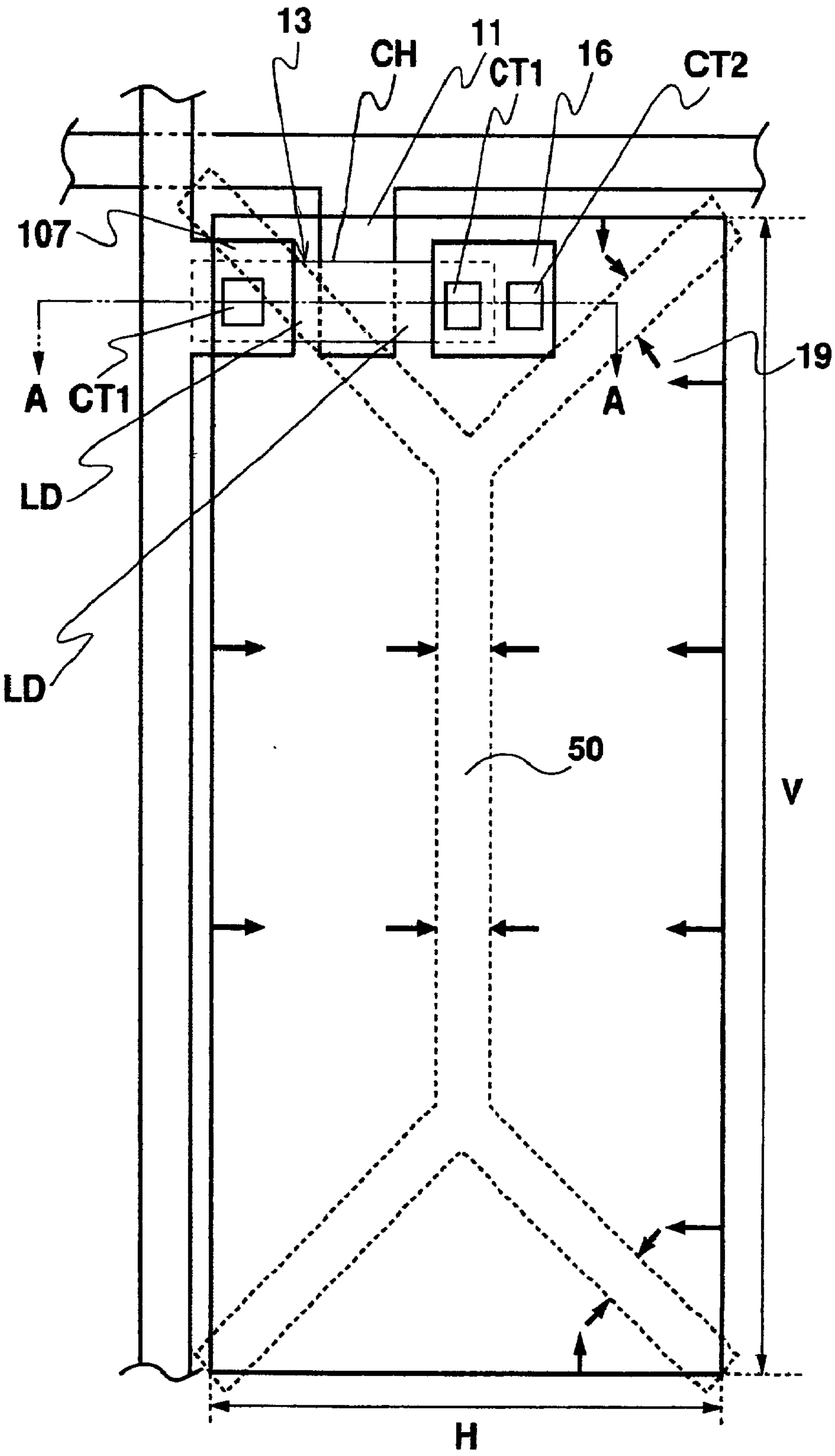


Fig. 3

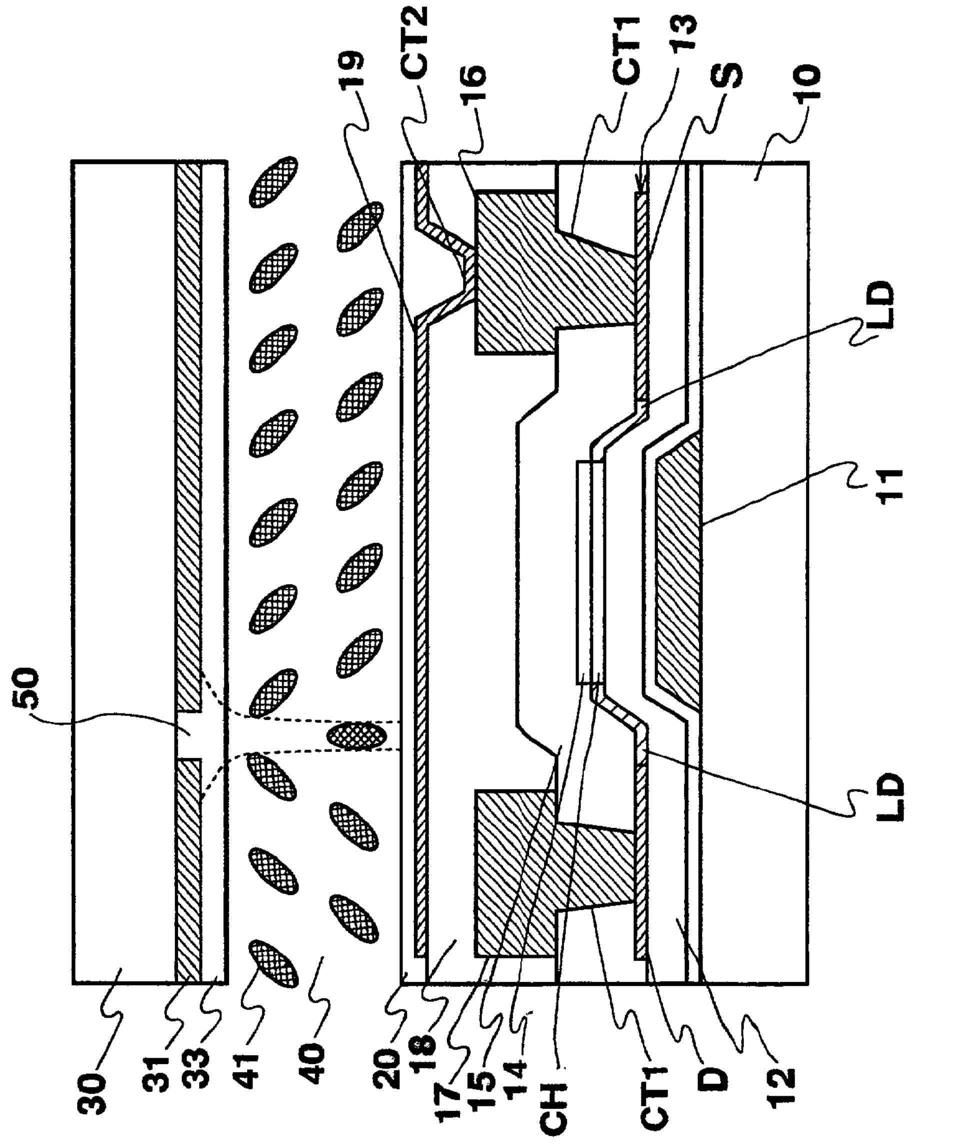

50
19
CT2
16
CT1
13
S
10
LD
11
LD
30
31
33
41
40
20
18
17
15
14
CH
CT1
D
12

Fig. 4

Fig. 5A

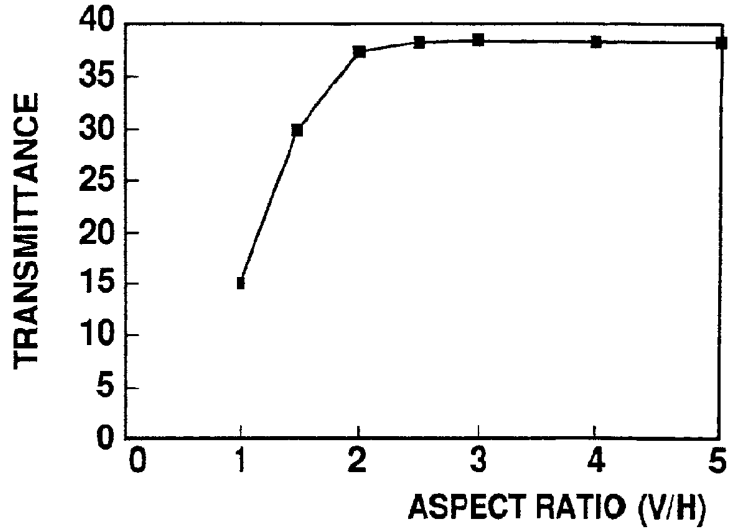
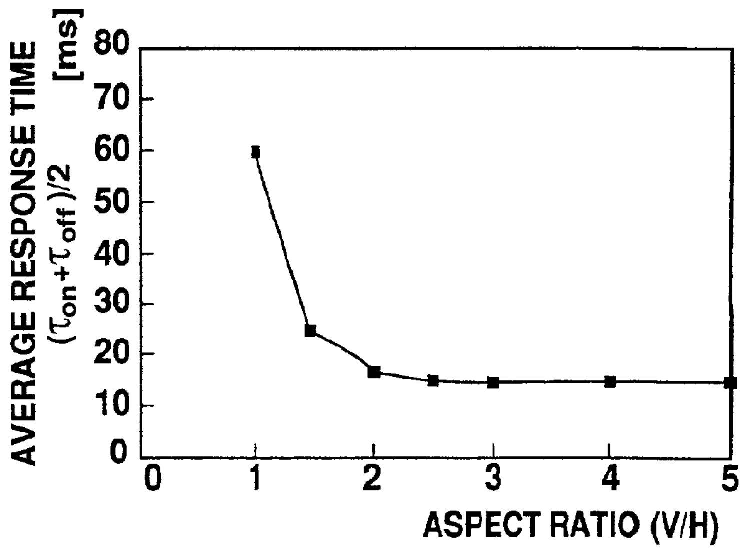

TRANSMITTANCE
40
35
30
25
20
15
10
5
0
0 1 2 3 4 5
ASPECT RATIO (V/H)

Fig. 5B


AVERAGE RESPONSE TIME
$(\tau_{on}+\tau_{off})/2$ [ms]
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70
60
50
40
30
20
10
0
0 1 2 3 4 5
ASPECT RATIO (V/H)

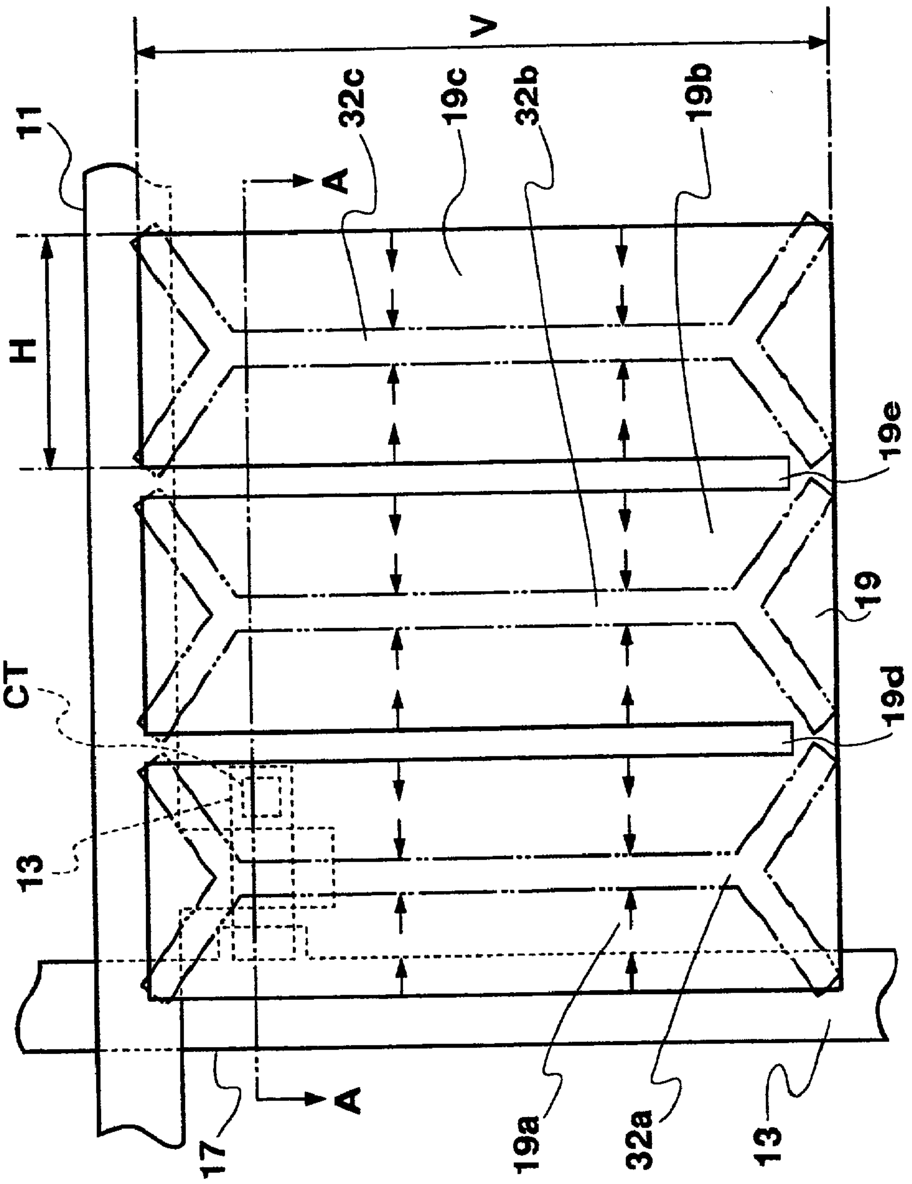

Fig. 6

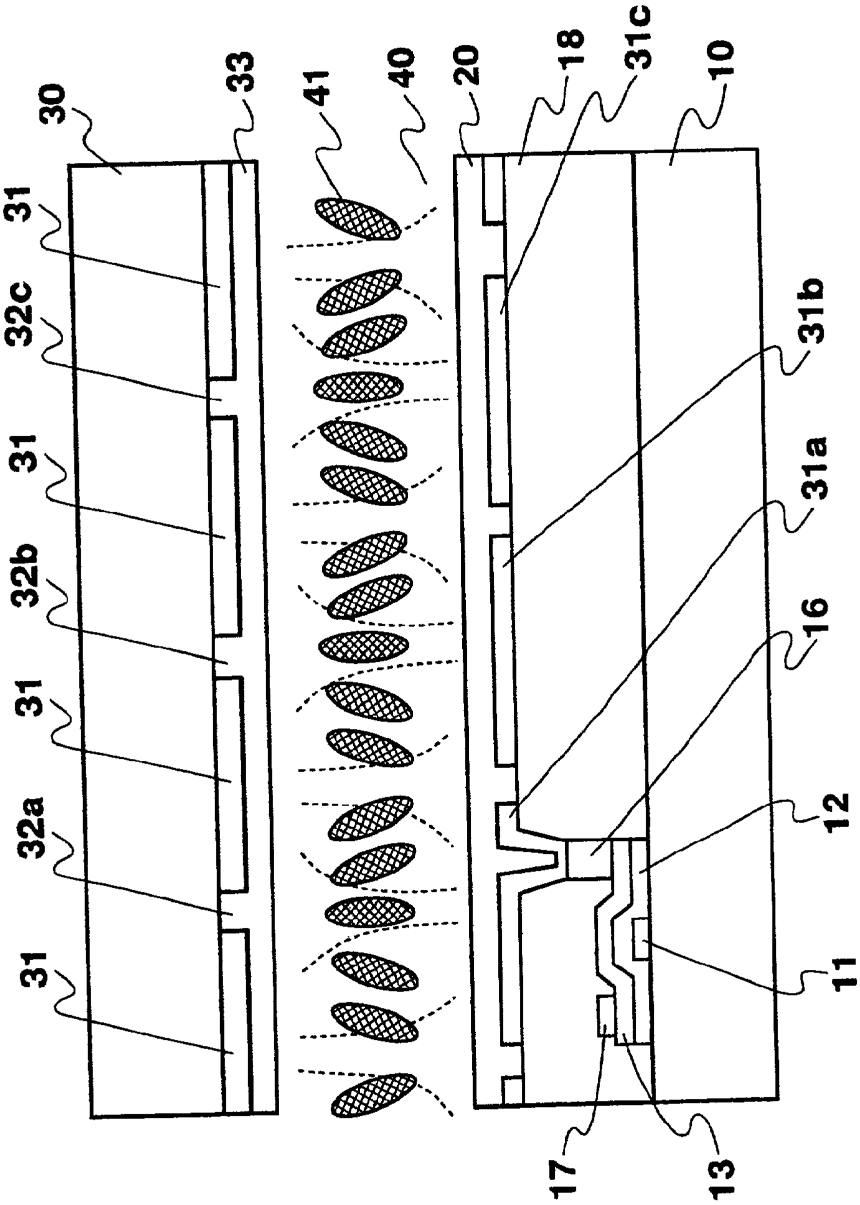
30
33
41
40
20
18
31c
10
31
32c
31
32b
31
32a
31
31b
31a
16
12
11
17
13

Fig. 7

LIQUID CRYSTAL DISPLAY INCLUDING A VERTICALLY ALIGNED LIQUID CRYSTAL LAYER DISPOSED BETWEEN PIXEL ELECTRODES AND A COMMON ELECTRODE

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a liquid crystal display (LCD) which utilizes opto-electric anisotropy of liquid crystal, and more particularly to a liquid crystal display which achieves an improved response speed and transmittance.

[0003] 2. Description of the Related Art

[0004] LCDs are compact, thin, and low power consumption devices and have been developed for practical use in the field of office automation (OA) and audio-visual (AV) equipment. In particular, active matrix type LCDs which utilize thin film transistors (TFTs) as switching elements are theoretically capable of static actuation at a duty ratio of 100% in a multiplexing manner, and have been used in large screen and high resolution type animation displays.

[0005] TFTs are field effect transistors arranged in a matrix on a substrate and connected to individual pixel electrodes which form one side of pixel capacitors with a dielectric layer made of liquid crystal. In a TFT matrix, TFTS located on a same row are simultaneously turned on/off by a given gate line, and each TFT of that row receives a pixel signal voltage from a given drain line. A display voltage is accumulated in the pixel capacitors corresponding to the on-state TFTs and designated by rows and columns. The pixel electrodes and the TFTs are formed on the same substrate, while a common electrode acting as the other side of the pixel capacitors is formed on the entire surface of the second substrate opposite to the first substrate across the liquid crystal layer. That is, the display pixels (i.e., pixels) are defined by partitioning the liquid crystal and the common electrode by pixel electrodes. The voltage accumulated in the pixel capacitors is held insulated by an off-state resistance of the TFTs for one field period or one frame period until the TFTs are turned on again. The liquid crystal is opto-electrically anisotropic, and its transmittance is controlled based on the voltage applied to respective pixel capacitors. The transmittance of each display pixel is independently controlled, so that individual pixels are observed bright or dark and recognized collectively as a display image by human eyes.

[0006] Initial orientation of the liquid crystal is determined by an orientation film disposed at the interface between the liquid crystal and each substrate. For example, a twisted nematic (TN) type LCD uses the liquid crystal in nematic phase which has positive dielectric anisotropy and whose alignment vectors are twisted 90 degrees between opposing substrates. Typically, a polarizing plate is provided on the outside of each substrate, and an polarizing axis of each polarizing plate coincides with the orientation of the liquid crystal located in the vicinity of the corresponding substrate. When no voltage is applied, linearly polarized light passes through one polarizing plate, turns its direction in the liquid crystal layer along the twisted alignment of the liquid crystal, and exits from the other polarizing plate, resulting in a "white" display. When the voltage is then applied to the pixel capacitors, an electric field is created within the liquid crystal and the orientation of the liquid crystal is changed to be parallel to the direction of the applied electric field because of dielectric anisotropy. This results in the collapse of twisted alignment and less frequent turns of the linearly polarized incoming light in the liquid crystal. Consequently, the amount of light ejecting from the other polarizing plate is reduced and the display gradually becomes black. This is known as a normally white mode which is widely applied in the field of TN cells, in which the display is white when no voltage is applied and changes to "black" upon application of the voltage.

[0007] **FIGS. 1 and 2** show a unit pixel structure of a conventional liquid crystal display, wherein **FIG. 1** is a plan view and **FIG. 2** is a sectional view along line G-G of **FIG. 1**. A gate electrode **101** made of a metal, such as Cr, Ta, or Mo, is formed on a substrate **100**, and a gate insulating film **102** made of, e.g., SiNx and/or SiO_2 is formed to cover the gate electrode **101**. The gate insulating film **102** is covered with a p-Si film **103** in which an implantation stopper **104** is used to form a lightly doped region (LD) having a low concentration (N−) of impurities, such as P or As, and source and drain regions (S, D) having a high concentration (N+) of impurities located outside the LD region. A region located immediately below the implantation stopper **104** is an intrinsic layer which includes substantially no impurities and acts as a channel region (CH). The p-Si **103** is covered with an interlayer insulating film **105** made of SiNx or the like. A source electrode **106** and a drain electrode **107**, both made of a material such as Al, Mo, or the like, are formed on the interlayer insulating film **105**, each electrode being connected to the source region S and the drain region D, respectively, via a contact hole CT**1** formed in the interlayer insulating film **105**. The entire surface of the thus formed TFT is covered with a planarization insulating film **108** made of SOG (spin on glass), BPSG (boro-phospho silicate glass), acrylic resin, or the like. A pixel electrode **109** made of ITO (indium tin oxide) or the like is formed on the planarization insulating film **108** for actuating the liquid crystal, and is connected to the source electrode **106** via a contact hole CT**2** formed in the planarization insulating film **108**.

[0008] An orientation film **120** formed by a high molecular film, such as polyimide, is disposed on the entire surface on the above elements and undergoes a rubbing treatment to control an initial orientation of the liquid crystal. Meanwhile, a common electrode **131** made of ITO is formed on the entire surface of another glass substrate **130** arranged opposite to the substrate **100** across a liquid crystal layer. The common electrode **131** is covered with an orientation film **133** made of polyimide or the like and undergone rubbing.

[0009] As shown herein, a DAP (deformation of vertically aligned phase) type LCD uses a nematic phase liquid crystal **140** having negative dielectric anisotropy, and orientation films **120**, **133** formed by a vertical orientation film. The DAP type LCD is one of the electrically controlled birefringence (ECB) type LCDs which use a difference of refractive indices of longer and shorter axes of a liquid crystal molecule, so-called a birefringence, to control transmittance. In the DAP type LCD, upon application of a voltage, an incoming light transmits one of two orthogonal polarization plates and enters the liquid crystal layer as a linearly polarized light, and is birefracted in the liquid crystal to become an elliptically polarized light. Then, retardation, which is a difference of phase velocity between ordinary and extraordinary ray components in the liquid crystal, is controlled according to an intensity of the electric field of the liquid crystal layer to allow the light to be emitted from the other polarization plate at a desired transmittance. In this case, the display is in a normally black mode, since the display is black when no voltage is applied and changes to white upon application of an appropriate voltage.

[**0010**] As described above, the liquid crystal display displays an image at an intended transmittance or color phase by applying a desired voltage to the liquid crystal sealed between a pair of substrates having predetermined electrodes formed thereon and by controlling a turning route or a birefringence of light in the liquid crystal. Specifically, the retardation is controlled by changing the alignment of the liquid crystal, to thereby adjust the light intensity of the transmitted light in the TN mode, while allowing the separation of color phases in the ECB mode by controlling a spectroscopic intensity depending on wavelength. Since the retardation depends on the angle between the longer axis of the liquid crystal molecule and the orientation of the electric field, the retardation still changes relative to the viewer's observation angle, i.e., a viewing angle, even when such an angle is primarily controlled by the adjustment of the electric field intensity. As the viewing angle changes, the light intensity or the color phase of the transmitted light also changes, causing a so-called viewing angle dependency problem.

[**0011**] Problems of decreased transmittance and slower response speed also remain.

SUMMARY OF THE INVENTION

[**0012**] The present invention is made to solve the above problems and provides a vertically aligned type liquid crystal display including a vertically aligned liquid crystal layer disposed between a plurality of pixel electrodes and a common electrode facing the plurality of pixel electrodes, wherein the orientation of the liquid crystal layer is controlled by electric field, the common electrode has an orientation control window formed in an area corresponding to each of the plurality of pixel electrodes, and a ratio of vertical to horizontal length of each of the plurality of pixel electrode is equal to or more than 2.

[**0013**] In another aspect of the present invention, a vertically aligned type liquid crystal display includes an orientation control window formed in a common electrode corresponding to each of a plurality of pixel electrodes, wherein each of the plurality of pixel electrodes is divided into two or more electrically connected electrode regions, and a ratio of vertical to horizontal length of each electrode region is larger than that of each of the plurality of pixel electrodes.

[**0014**] In still another aspect of the present invention, a liquid crystal display includes a plurality of pixel electrodes, each pixel electrode being divided into two or more electrically connected electrode regions having a vertical to horizontal length ratio of equal to or more than 2.

[**0015**] In a further aspect of the present invention, the orientation control window is in the form of a slit which extends longitudinally in an area corresponding to the center part of each pixel electrode or electrode region.

[**0016**] In a still further-aspect of the present invention, the orientation control window is in the form of a slit which forks at both longitudinal ends of the electrode or electrode region toward corner sections of the pixel electrode.

[**0017**] In addition, each pixel electrode may be divided into a plurality of electrode regions, and one orientation control window is formed for each electrode region.

[**0018**] The present invention includes the above features and reduces the influence at edge sections of the pixel electrodes by the combination of the above-mentioned orientation control window and the pixel electrodes, thereby achieving improved viewing angle characteristic and transmittance and a reduced average response time of the display.

[**0019**] As is apparent from the above description, the influence at the edge sections of the pixel electrode is reduced, the viewing angle characteristic and the transmittance are improved, and the average response time is shortened by setting an aspect ratio (V/H) of each pixel electrode or divided pixel electrode to at least a predetermined value.

BRIEF DESCRIPTION OF THE DRAWINGS

[**0020**] **FIG. 1** is a plan view showing a unit pixel of a conventional liquid crystal display;

[**0021**] **FIG. 2** is a sectional view taken along line G-G of **FIG. 1**;

[**0022**] **FIG. 3** is a plan view showing a unit pixel of a liquid crystal display according to a first embodiment of the present invention;

[**0023**] **FIG. 4** is a sectional view taken along line A-A of **FIG. 3**;

[**0024**] **FIGS. 5A and 5B** are graphs plotting an aspect ratio of the liquid crystal display as a function of a transmittance and an average response time, respectively, according to the present invention;

[**0025**] **FIG. 6** is a plan view showing a unit pixel of the liquid crystal display according to a second embodiment of the present invention; and

[**0026**] **FIG. 7** is a sectional view taken along line A-A of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[**0027**] Referring to **FIGS. 3 and 4**, a unit pixel structure of a liquid crystal display according to the present invention is shown, wherein **FIG. 3** is a plan view and **FIG. 4** is a sectional view taken along line A-A of **FIG. 3**. A gate electrode **11** made of a metal, such as Cr, Ta, or Mo, is formed on a substrate **10**, and a gate insulating film **12** made of, e.g., SiNx and/or SiO_2 is formed to cover the gate electrode **11**. The gate insulating film **12** is covered with p-Si **13** in which an implantation stopper **14** is used to form a lightly doped region (LD) having a low concentration (N−) of impurities, such as P or As, and source and drain regions (S, D) having a high concentration (N+) of impurities located outside the LD region. A region located immediately below the implantation stopper **14** is an intrinsic layer which includes substantially no impurities and acts as a channel region (CH). The p-Si **13** is covered with an interlayer insulating film **15** made of SiNx or the like. A source electrode **16** and a drain electrode **17**, both made of Al, Mo, or the like, are formed on the interlayer insulating film **15**, each electrode being connected to the source region S and the drain region D, respectively, via a contact hole CT1 formed in the interlayer insulating film **15**. The entire surface of the thus formed TFT is covered with a planarization insulating film **18** made of SOG (spin on glass), BPSG (boro-phospho silicate glass), acrylic resin, or the like. A pixel electrode **19** made of ITO (indium tin oxide) or the like is formed on the planarization insulating film **18** for actuating the liquid crystal, and is connected to the source electrode **16** via a contact hole CT2 formed in the planarization insulating film **18**.

[0028] An orientation film **20** formed by a macro molecular film, such as polyimide, is formed on the entire surface of the above elements, while a common electrode **31** made of ITO is formed on the entire surface of another glass substrate **30** arranged opposite to the substrate **10** across a liquid crystal layer. The common electrode **31** is covered with an orientation film **33** made of polyimide or the like. In the present invention, the orientation films **20**, **33** and the liquid crystal **40** are selected so that liquid crystal molecules **41** are aligned vertically.

[0029] In addition, an orientation control window **50** is formed in the common electrode **31** facing the pixel electrode **19** and in the form of two upper and lower Y-shaped slits connected symmetrically to each other. More specifically, this window **50** is in the form of a slit which extends in a straight line along a longer edge of the pixel electrode **19** in an area corresponding to the center part of the pixel electrode **19**, and forks at an area corresponding to both longitudinal ends of the pixel electrode **19** toward its corner sections. Since the electric field applied to the liquid crystal molecules **41** located below the orientation control window **50** is not sufficiently strong to tilt those molecules **41**, they have vertical alignment. Around these molecules **41**, however, the electric field is created as indicated by a dotted line in **FIG. 4**, which controls the molecules **41** to direct their longer axes perpendicular to the applied field. This is also true at the edge sections of the pixel electrode **19** and the longer axes of the liquid crystal molecules **41** are oriented perpendicularly to the electric field. The tilt of these molecules is propagated to other molecules located in the interior of the layer because of continuity of the liquid crystal. Thus, the liquid crystal molecules are oriented in substantially the same direction in the center part of the pixel electrode **19**, but the orientation is uneven in the vicinity of the edge sections. It has been found that better viewing angle characteristic and transmittance are achieved when the orientation is uniform.

[0030] To achieve this, the present invention sets an aspect ratio, i.e., a vertical to horizontal length ratio V/H of the pixel electrode **19** facing the orientation control window **50** to at least 2. As such, it is possible to enlarge an area where the liquid crystal molecules are oriented in the same direction, while decreasing the share of an unevenly oriented area. This allows the viewing angle characteristic, the transmittance, and even the response speed to be improved.

[0031] **FIGS. 5A and 5B** show the experimental results, and plot an aspect ratio (V/H) of the pixel electrode **19** relative to its transmittance and average response time ((τ on+τ off)/2), respectively. As shown in the graph of **FIG. 5A**, the transmittance was low until the aspect ratio reached 2, and then increased to a preferable value and remained on that value. As shown in the graph of **FIG. 5B**, the average response time was slow until the aspect ratio reached 2, and then accelerated and generally remained unchanged after that. Namely, at the aspect ratio of the pixel electrode **19** equal to 2 or more, a higher transmittance and a reduced average response time were achieved.

[0032] Referring next to **FIGS. 6 and 7**, a second embodiment of the present invention will be described.

[0033] **FIG. 6** is a plan view showing a unit pixel structure of the liquid crystal display and **FIG. 7** is a sectional view taken along line A-A of **FIG. 6**. It is to be noted, that for the sake of clarity the TFT structure is not shown in **FIG. 7**, but it is of the same structure as that shown in **FIG. 4**.

[0034] In this embodiment, the vertical length of the pixel electrode **19** corresponding to the unit pixel is longer than the horizontal length. Thus, slits **19*d*** and **19*e*** are formed vertically like a comb in the pixel electrode **19**, dividing (or equally dividing in this embodiment) it into three pixel electrode regions **19*a*, 19*b*,** and **19*c*** to set the aspect ratio V/H of each pixel electrode region to 2 or more. It is to be noted, however, these pixel electrode regions **19*a***, **19*b***, and **19*c*** are partly connected to each other under the slits **19*d*** and **19*e***, because one display pixel corresponds to one pixel.

[0035] Orientation control windows **32*a***, **32*b***, and **32*c*** are formed in the common electrode **31** facing the substrate **30**, each window corresponding to each pixel electrode section **19*a***, **19*b***, and **19*c***. In each pixel electrode section **19*a***, **19*b***, or **19*c***, the liquid crystal molecules are oriented in reverse about each orientation control window. This increases an uniform orientation area of the liquid crystal molecules, while decreasing an abnormal orientation area at the edge sections of the pixel electrode. Thus, the viewing angle characteristic, transmittance, and response time are also improved, as in the above embodiment.

What is claimed is:

1. A vertically aligned type liquid crystal display, comprising:

a vertically aligned liquid crystal layer disposed between a plurality of pixel electrodes and a common electrode, the orientation of said liquid crystal layer being controlled by electric field;

wherein said common electrode has an orientation control window formed in an area corresponding to each of said plurality of pixel electrodes, and

wherein a ratio of vertical to horizontal length of each of said plurality of pixel electrodes is equal to or more than 2.

2. The liquid crystal display according to claim 1,

wherein said orientation control window is in the form of a slit which extends along a longer edge of said pixel electrode in an area corresponding to the center part of said pixel electrode.

3. The liquid crystal display according to claim 2,

wherein said orientation control window is in the form of a slit which forks at both longitudinal ends of said pixel electrode toward corner sections of said pixel electrode.

4. A vertically aligned type liquid crystal display, comprising:

a vertically aligned liquid crystal layer disposed between a plurality of pixel electrodes and a common electrode, the orientation of said liquid crystal layer being controlled by electric field;

wherein said common electrode has an orientation control window formed in an area corresponding to each of said plurality of pixel electrodes, and

wherein each of said plurality of pixel electrodes is divided into two or more electrically connected electrode regions, and a vertical to horizontal length ratio of each electrode region is larger than that of each of said plurality of pixel electrodes.

5. The liquid crystal display according to claim 4, wherein one orientation control window is formed for each said electrode region.

6. The liquid crystal display according to claim 4,

wherein one orientation control window is formed for each said electrode region, and

wherein each of said orientation control windows is in the form of a slit which extends along a longer edge of said electrode region corresponding to the center part of said electrode region.

7. The liquid crystal display according to claim 6,

wherein said orientation control window is in the form of a slit which forks at both longitudinal ends of said electrode region toward corner sections of said electrode region.

8. A vertically aligned type liquid crystal display, comprising:

a vertically aligned liquid crystal layer disposed between a plurality of pixel electrodes and a common electrode, the orientation of said liquid crystal layer being controlled by electric field;

wherein said common electrode has an orientation control window formed in an area corresponding to each of said plurality of pixel electrodes, and,

wherein each of said plurality of pixel electrodes is divided into two or more electrically connected electrode regions, and a vertical to horizontal length ratio of each electrode region is equal to or more than 2.

9. The liquid crystal display according to claim 8,

wherein one orientation control window is formed for each said electrode region.

10. The liquid crystal display according to claim 8,

wherein one orientation control window is formed for each said electrode region, and

wherein each of said orientation control windows is in the form of a slit which extends along a longer edge of said electrode region in an area corresponding to the center part of said electrode region.

11. The liquid crystal display according to claim 10,

wherein said orientation control window is in the form of a slit which forks at both longitudinal ends of said electrode region toward corner sections of said electrode region.

* * * * *

专利名称(译)	液晶显示器包括设置在像素电极和公共电极之间的垂直排列的液晶层		
公开(公告)号	US20010004277A1	公开(公告)日	2001-06-21
申请号	US09/768371	申请日	2001-01-23
[标]申请(专利权)人(译)	三洋电机株式会社		
申请(专利权)人(译)	SANYO ELECTRIC CO. , LTD.		
当前申请(专利权)人(译)	SANYO ELECTRIC CO. , LTD.		
[标]发明人	KOMA NORIO		
发明人	KOMA, NORIO		
IPC分类号	G02F1/1337 G02F1/1333 G02F1/1343 G02F1/136 G02F1/1368 G02F1/139		
CPC分类号	G02F1/133707 G02F1/1343 G02F2001/134318 G02F2201/121 G02F1/1393		
优先权	1997268973 1997-10-01 JP		
其他公开文献	US6407794		
外部链接	Espacenet USPTO		

摘要(译)

垂直取向型液晶显示器包括设置在像素电极和公共电极之间并包含垂直取向的液晶分子的液晶层，液晶分子的取向受电场控制。在与像素电极相对的公共电极中形成取向控制窗口，并且纵横比，即像素电极的垂直与水平长度比被设置为至少2.或者，像素电极至少被划分为两个电极区域，每个区域代表划分的像素电极。在公共电极中形成取向控制窗口以对应于每个划分的像素电极，每个划分的像素电极的纵横比被设置为至少2.这样，降低了像素电极的边缘部分的影响。，视角特性和透光率得到改善，平均响应时间缩短。