



US008174472B2

(12) **United States Patent**  
**Lee**

(10) **Patent No.:** **US 8,174,472 B2**  
(45) **Date of Patent:** **\*May 8, 2012**

(54) **LIQUID CRYSTAL DISPLAY AND METHOD THEREOF**

(75) Inventor: **Min-Cheol Lee**, Seoul (KR)

(73) Assignee: **Samsung Electronics Co., Ltd.** (KR)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **13/097,579**

(22) Filed: **Apr. 29, 2011**

(65) **Prior Publication Data**

US 2011/0205462 A1 Aug. 25, 2011

**Related U.S. Application Data**

(62) Division of application No. 11/445,412, filed on Jun. 1, 2006, now Pat. No. 7,956,942.

(30) **Foreign Application Priority Data**

Jun. 1, 2005 (KR) ..... 10-2005-0046911

(51) **Int. Cl.**  
**G09G 3/36** (2006.01)

(52) **U.S. Cl.** ..... **345/87; 345/92; 345/99; 345/73; 345/694; 345/695; 349/38; 349/39**

(58) **Field of Classification Search** ..... None  
See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

5,610,739 A 3/1997 Uno et al.  
5,852,485 A 12/1998 Shimada et al.

6,028,581 A	2/2000	Umeya	
6,411,346 B1	6/2002	Numano et al.	
7,071,911 B2 *	7/2006	Inukai	345/92
7,084,848 B2 *	8/2006	Senda et al.	345/92
7,098,989 B2 *	8/2006	Wu	349/192
7,453,086 B2 *	11/2008	Kim et al.	257/59
7,796,104 B2 *	9/2010	Kim	345/87
2003/0076451 A1 *	4/2003	Hector et al.	349/43
2005/0122441 A1	6/2005	Shimoshikiryoh	
2006/0119756 A1 *	6/2006	Shin et al.	349/38
2006/0152641 A1 *	7/2006	Brody	349/38

**FOREIGN PATENT DOCUMENTS**

JP	05333376	12/1993
JP	08179341	7/1996
JP	09189922	7/1997
JP	2000002889	1/2000
JP	2002333870	11/2002
JP	2004145266	5/2004
JP	2004213011	7/2004
JP	2004258598	9/2004
JP	2004272259	9/2004

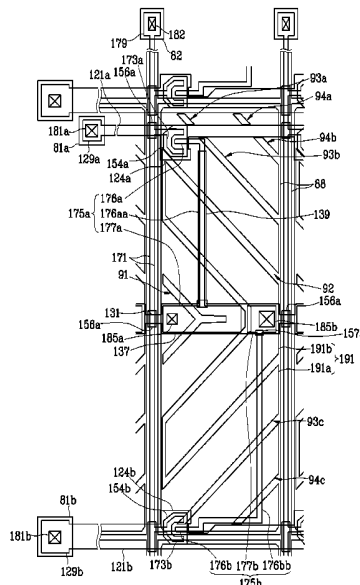
(Continued)

*Primary Examiner* — Richard Hjerpe  
*Assistant Examiner* — Christopher Thompson  
(74) *Attorney, Agent, or Firm* — Cantor Colburn LLP

(57) **ABSTRACT**

A liquid crystal display includes a first gate electrode, a storage electrode having a body and an extension, a first semiconductor formed on a gate insulating layer, a first drain electrode formed on the first semiconductor, separated from a first source electrode, and having an end portion overlapping the first gate electrode, and an expansion overlapping the body of the storage electrode and distanced from the end portion with a connection connecting the end portion and the expansion and overlapping the extension of the storage electrode, a passivation layer having a contact hole exposing the expansion of the first drain electrode, and a first field-generating electrode connected to the first drain electrode through the contact hole.

**6 Claims, 19 Drawing Sheets**



# US 8,174,472 B2

Page 2

---

## FOREIGN PATENT DOCUMENTS

KR	1020040056970	7/2004
KR	1020040062752	7/2004
KR	1020040084019	10/2004

KR	1020040105934	12/2004
KR	1020050018520	2/2005
WO	2004086129	10/2004

\* cited by examiner

FIG. 1A

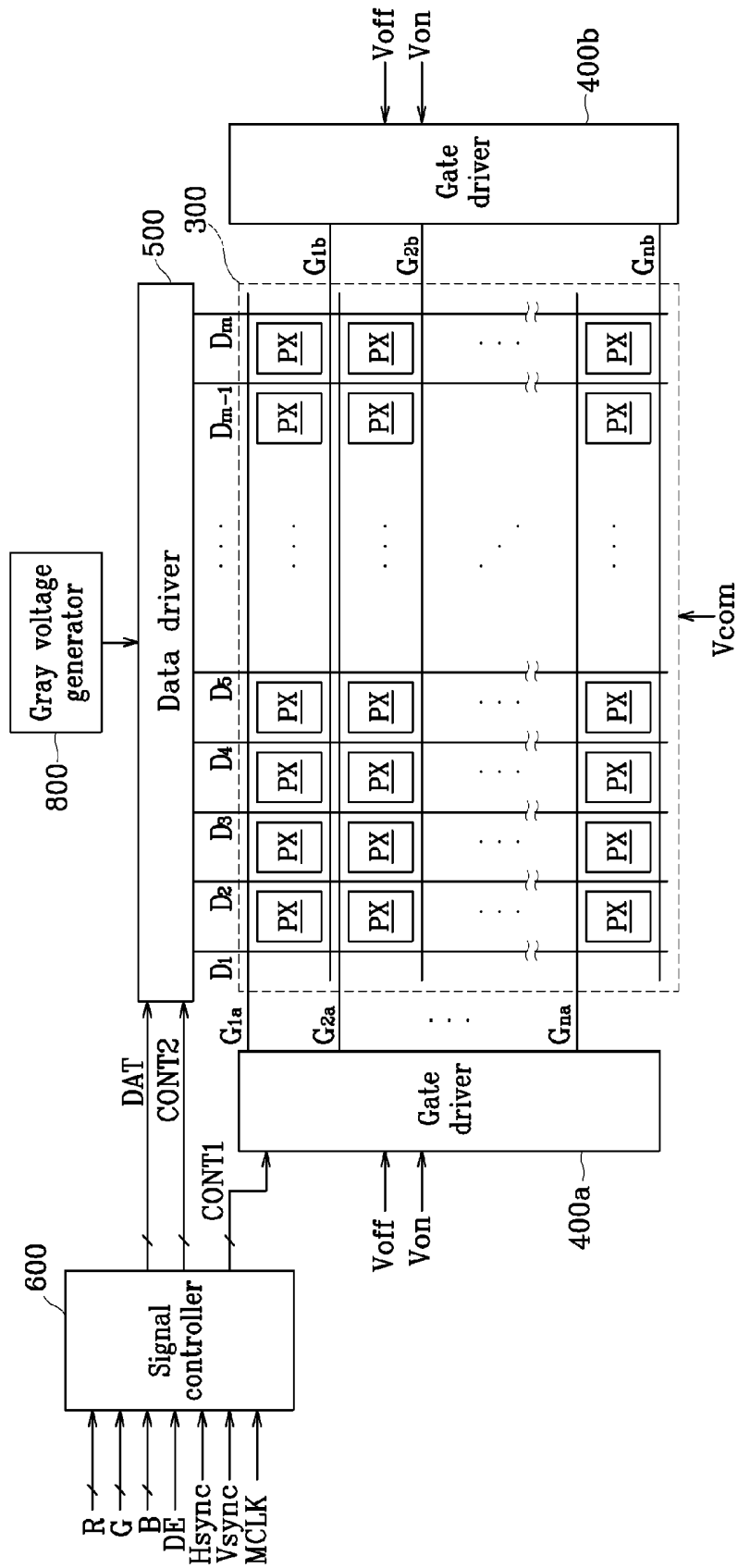


FIG. 1B

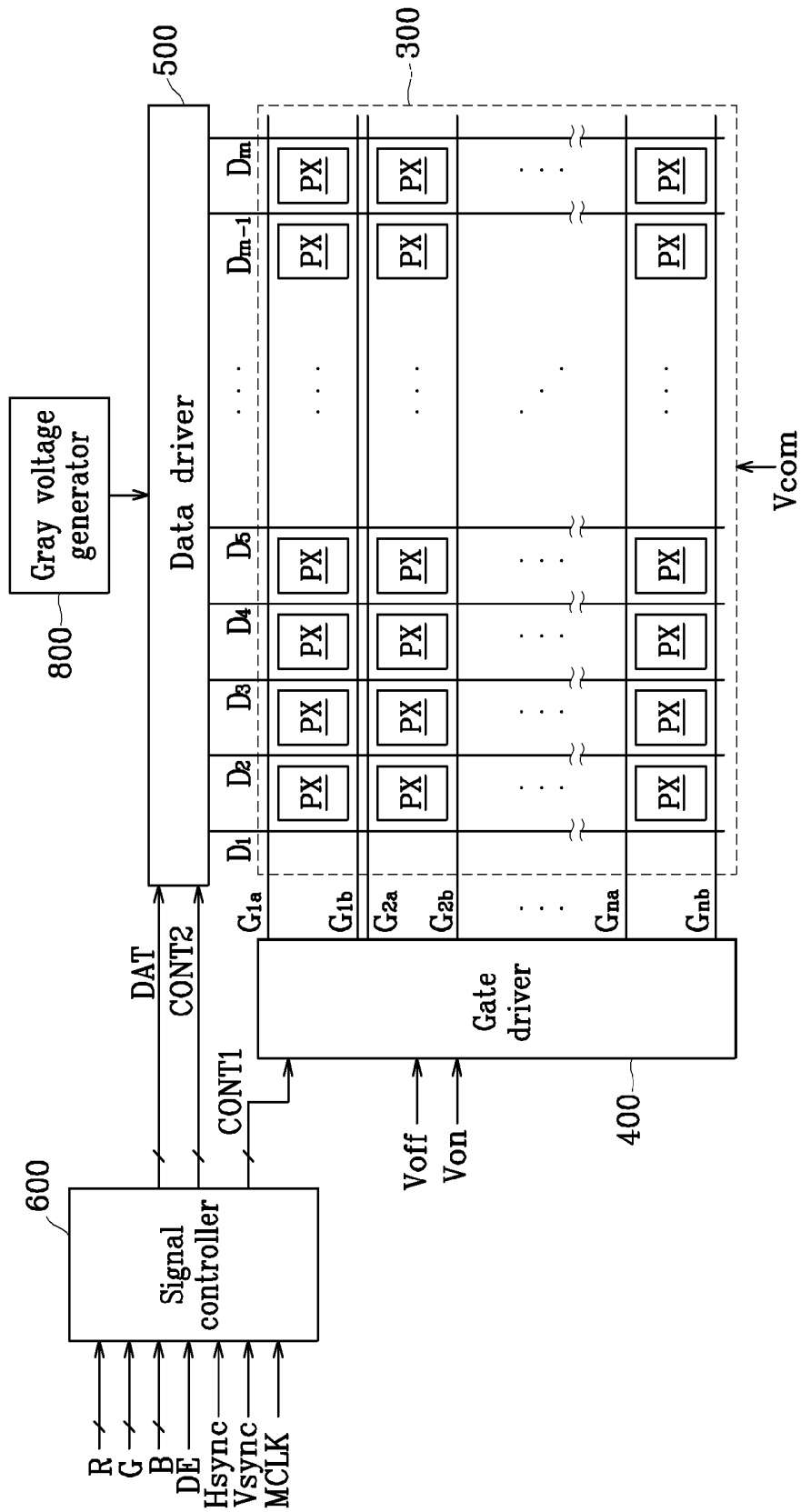


FIG. 1C

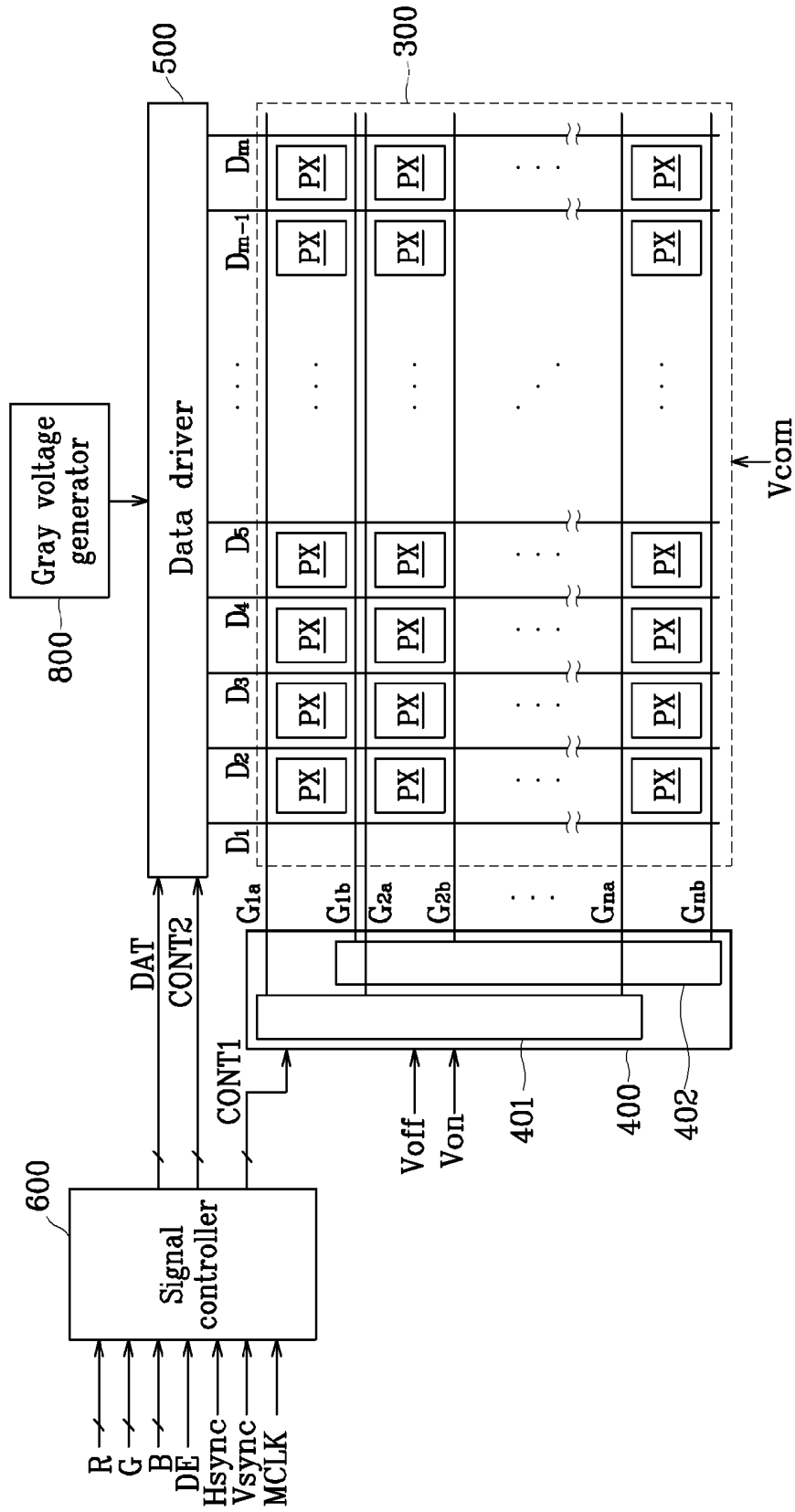


FIG. 2

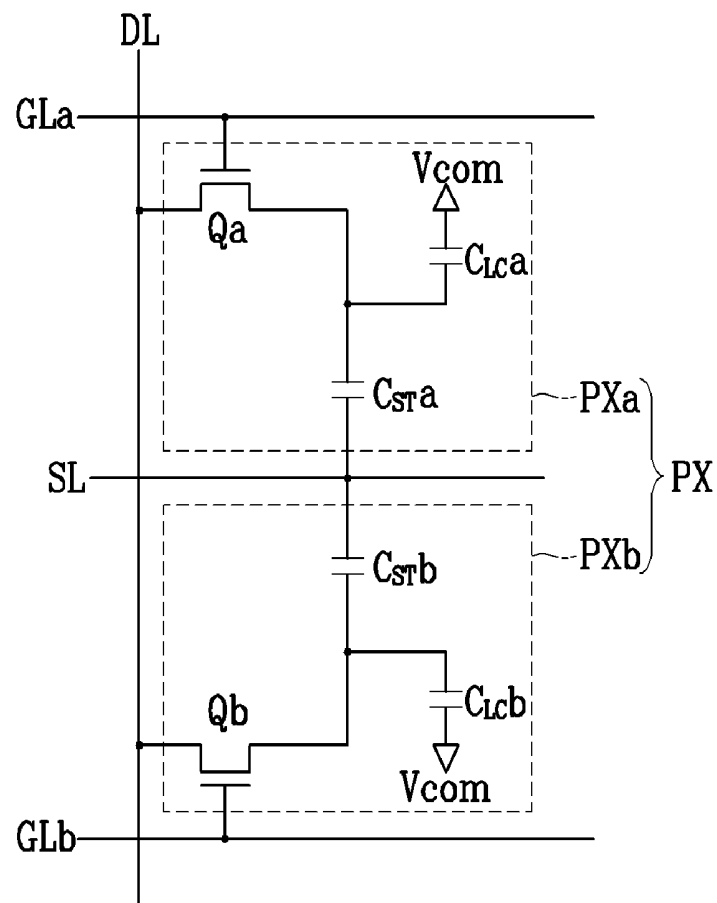


FIG. 3

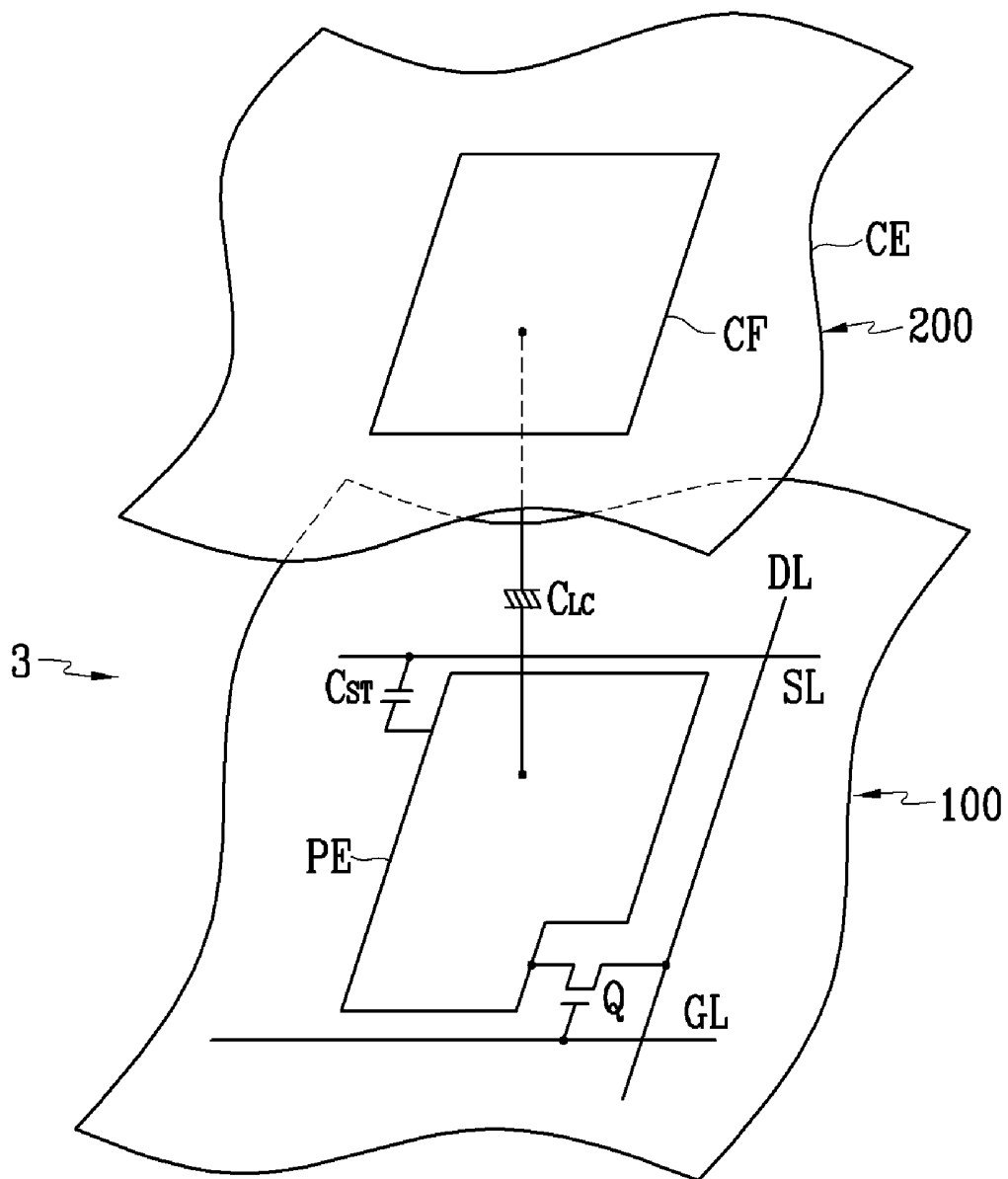


FIG. 4

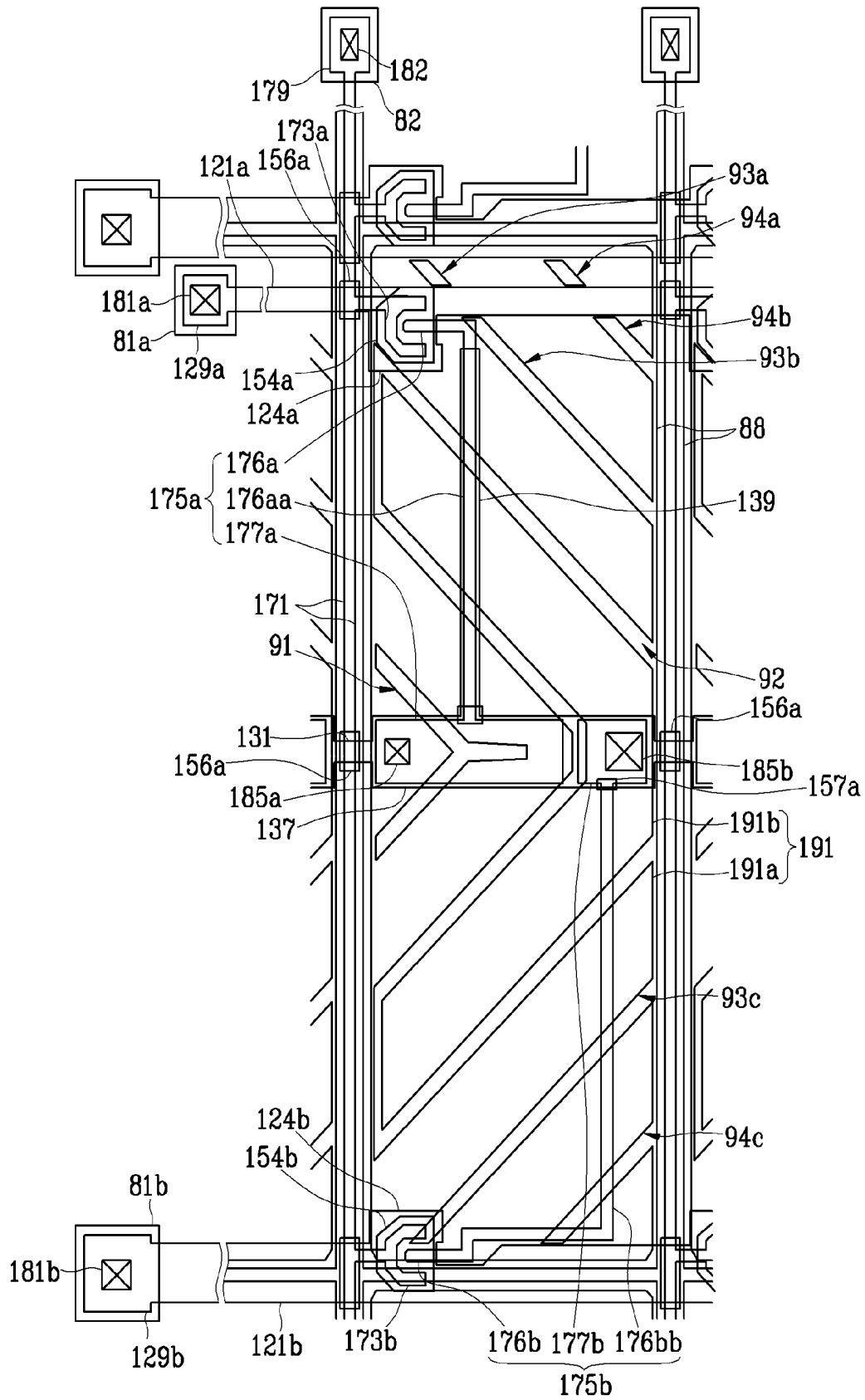


FIG. 5

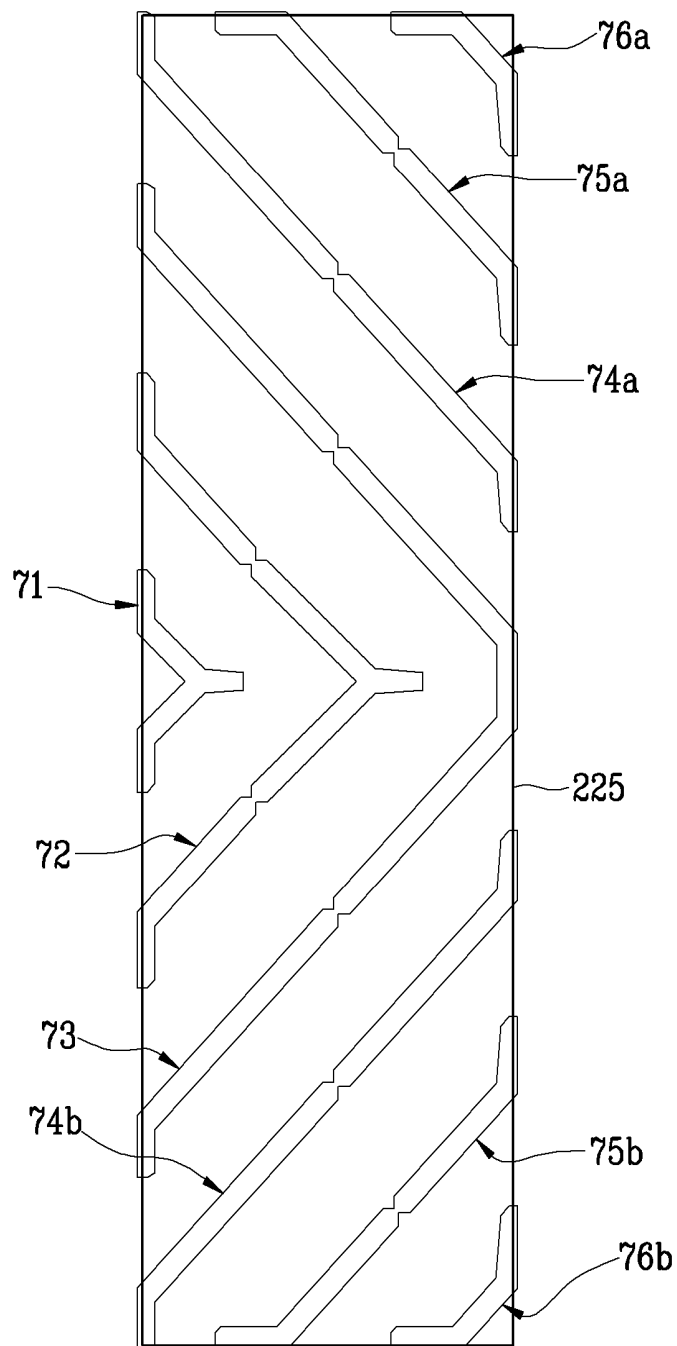






FIG. 7B

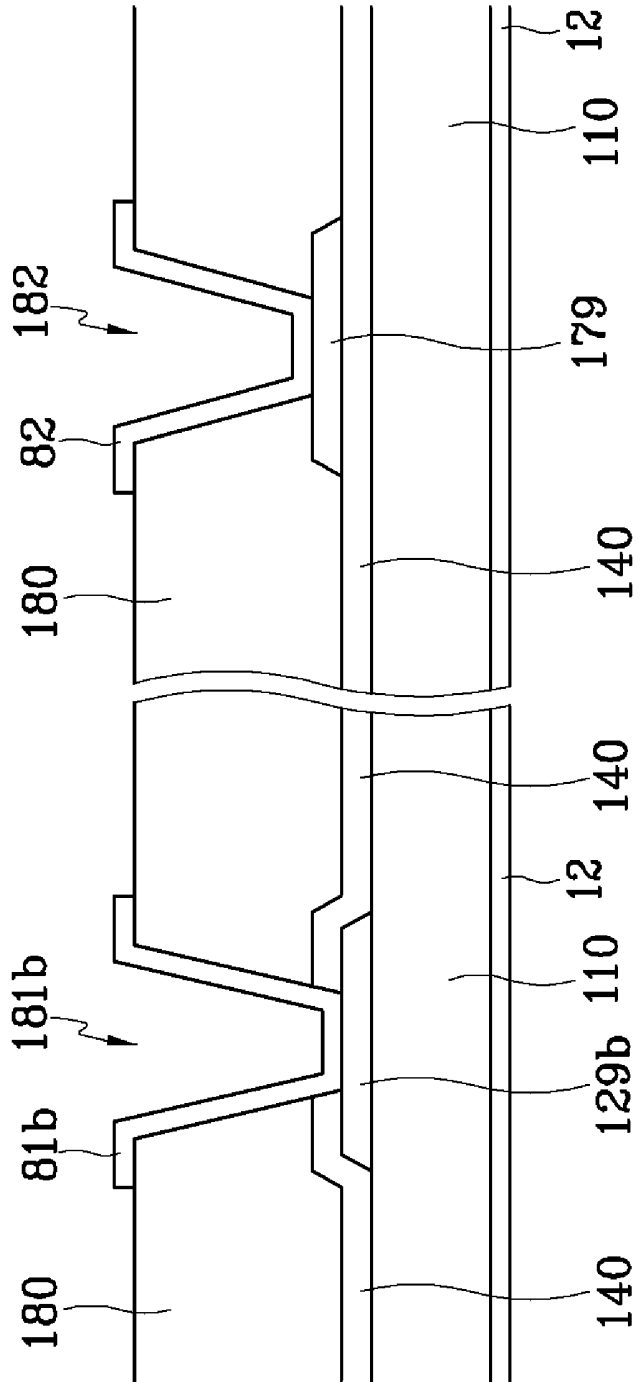




FIG. 9

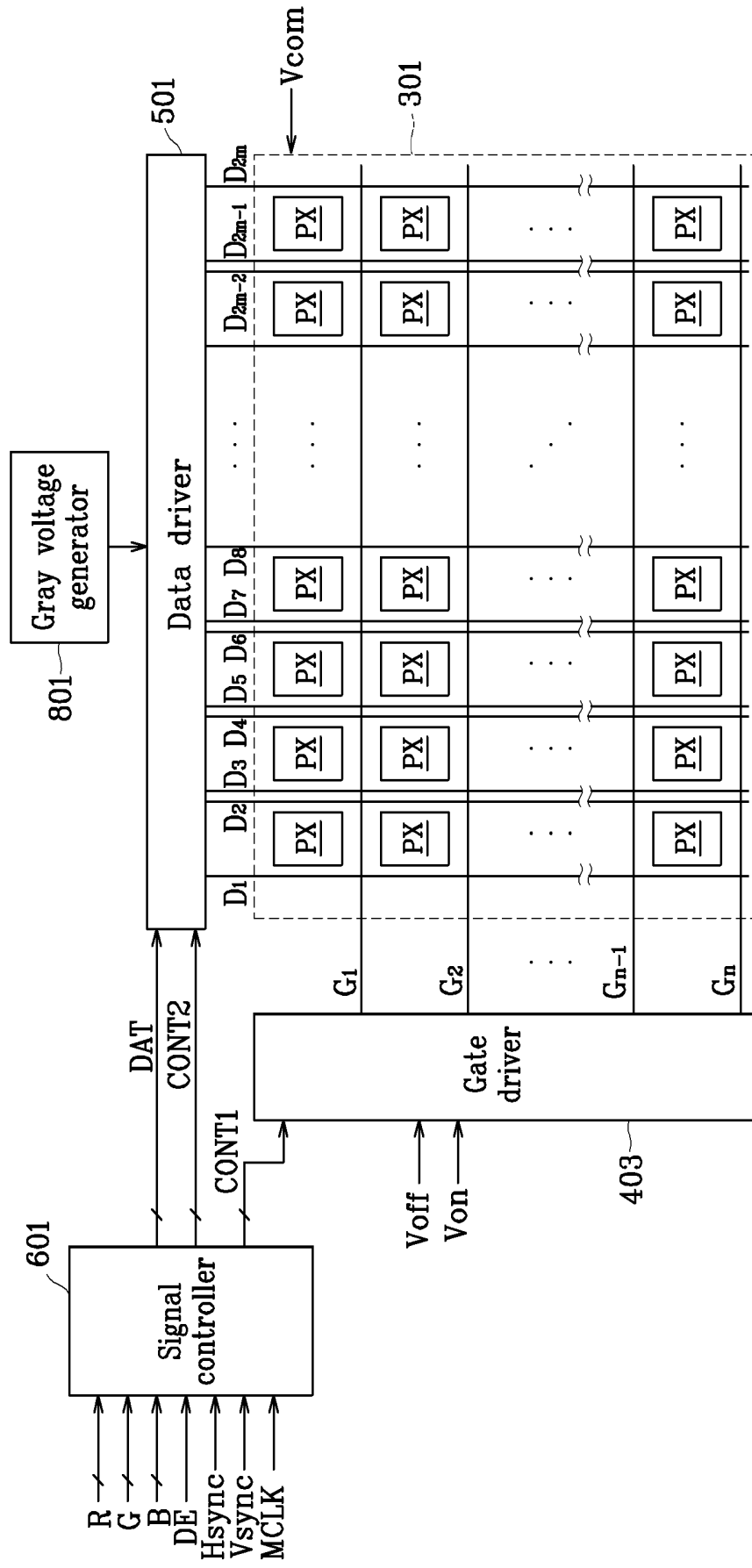




FIG. 11

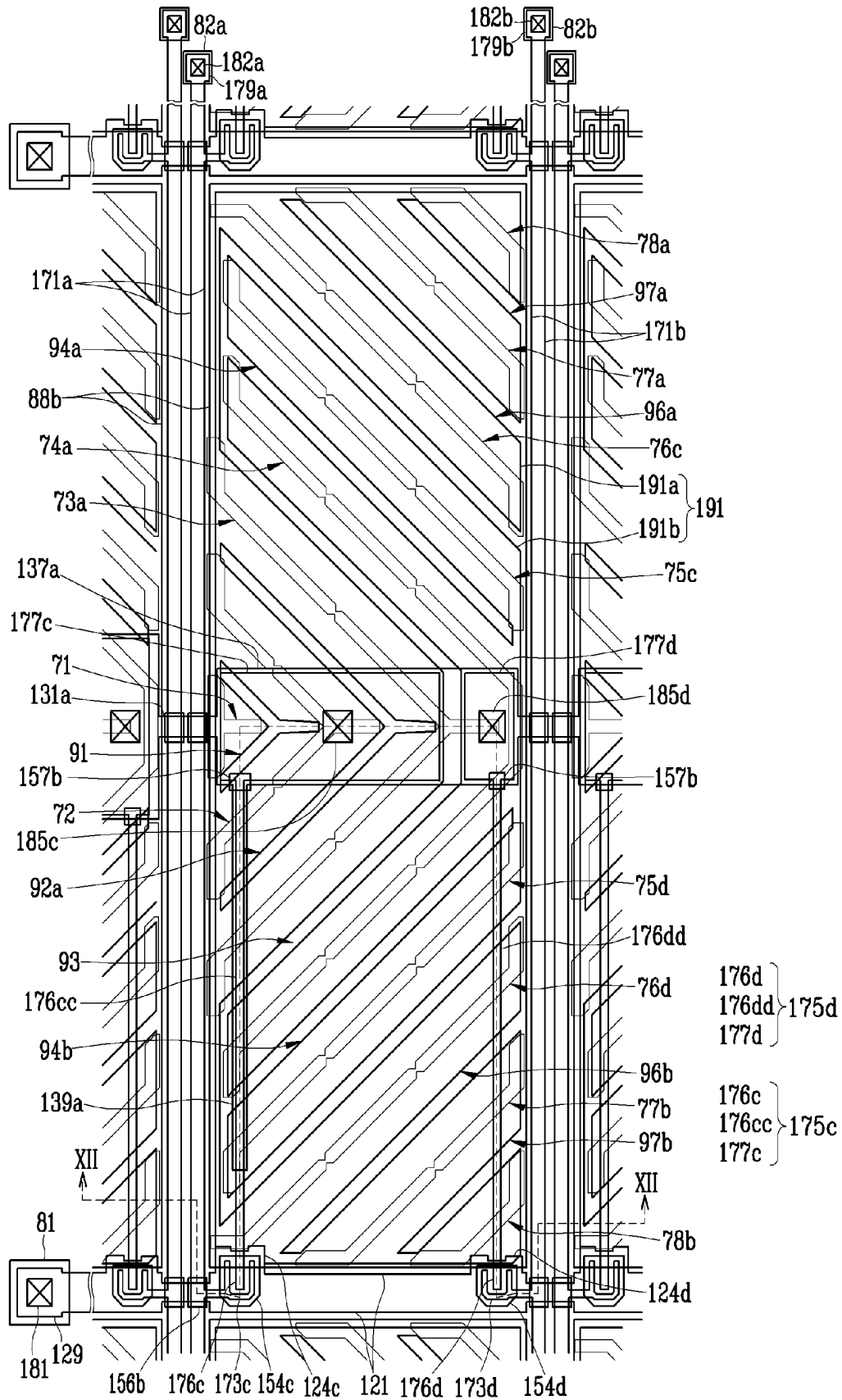




FIG. 13A

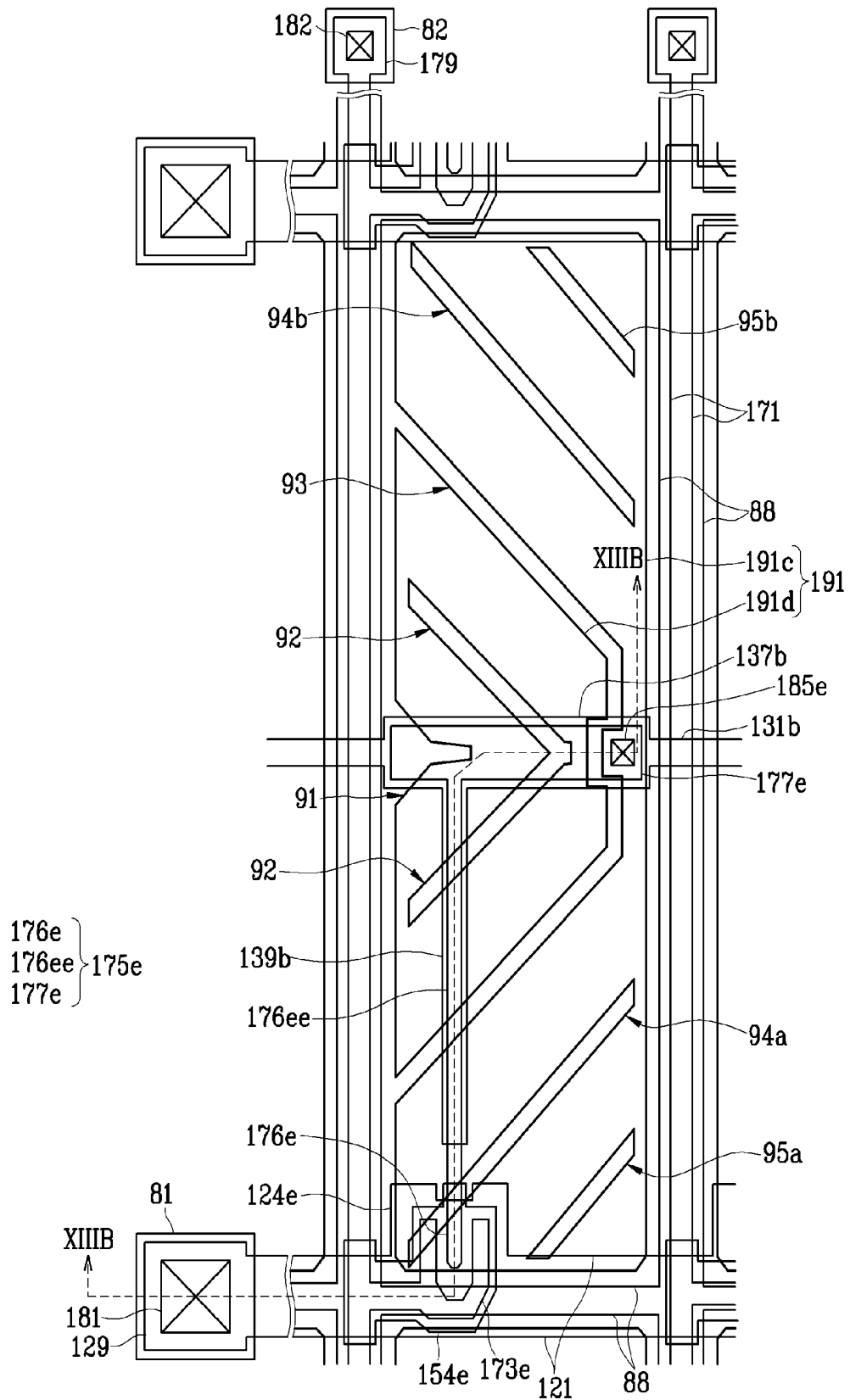


FIG. 13B

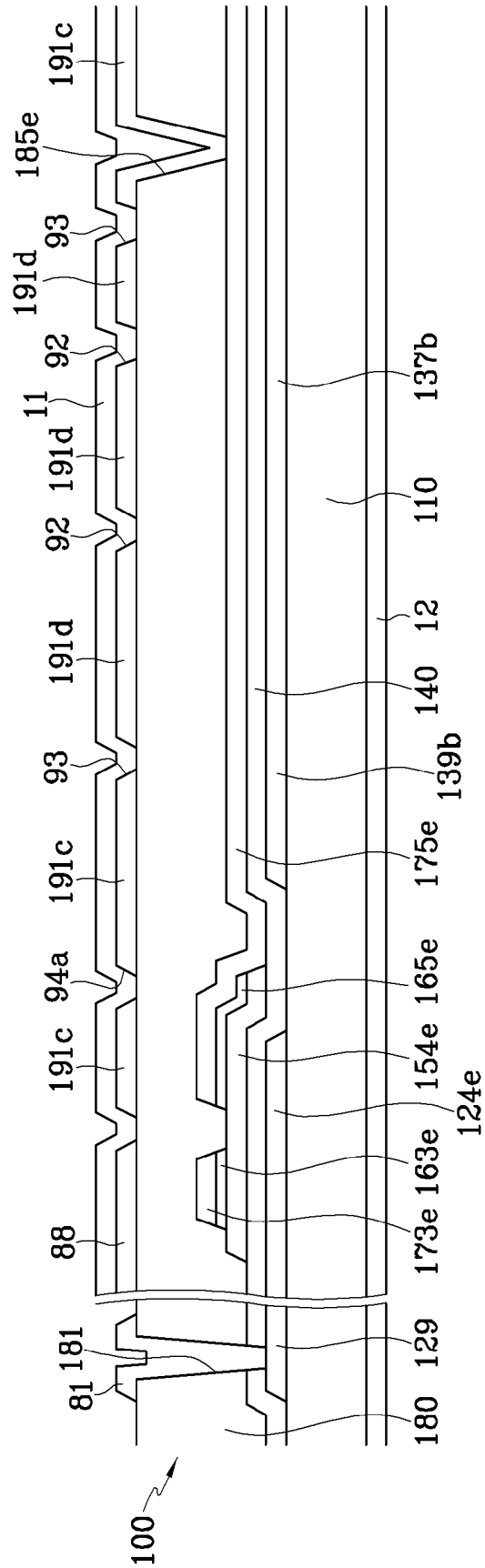


FIG. 14A

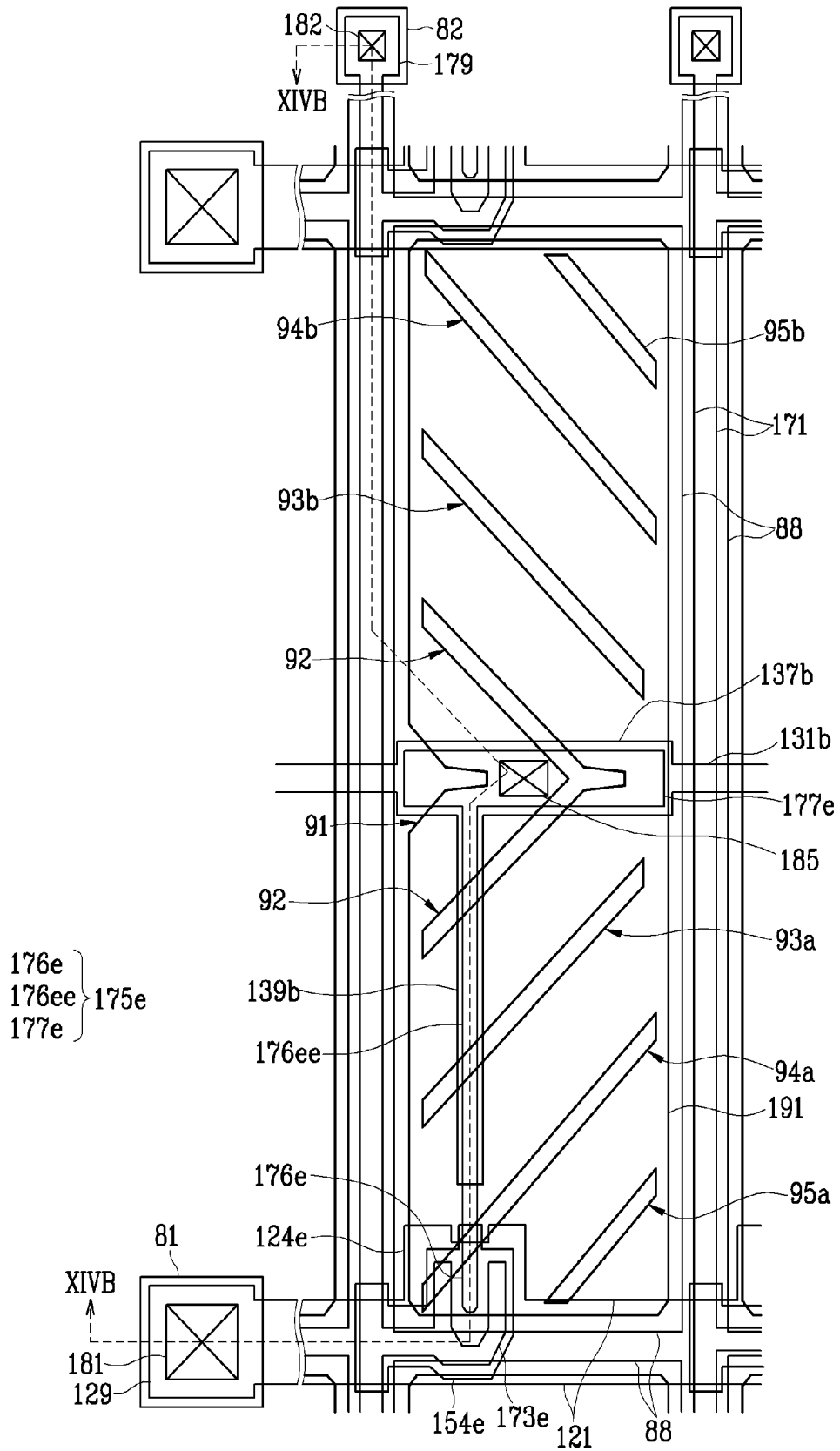
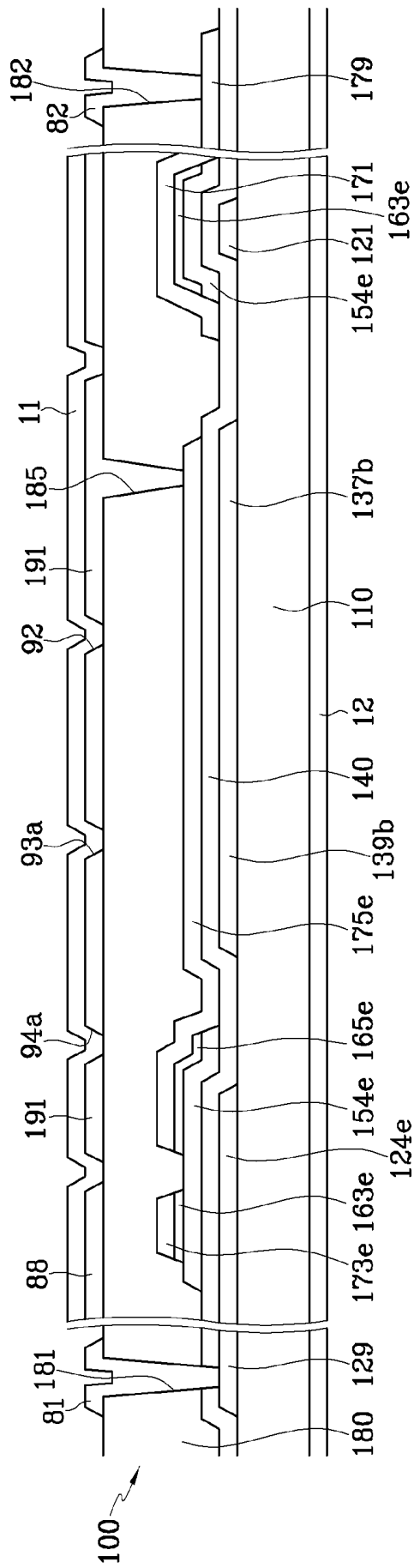


FIG. 14B



# LIQUID CRYSTAL DISPLAY AND METHOD THEREOF

## CROSS REFERENCE TO RELATED APPLICATIONS

This application is a divisional of U.S. application Ser. No. 11/445,412, filed on Jun. 1, 2006, which claims priority to Korean Patent Application No. 10-2005-0046911, filed on Jun. 1, 2005 and all the benefits accruing therefrom under 35 U.S.C. §119, and the contents of which in its entirety are herein incorporated by reference.

## BACKGROUND OF THE INVENTION

### (a) Field of the Invention

The present invention relates to a liquid crystal display ("LCD") and method thereof. More particularly, the present invention relates to an LCD improving lateral visibility, and a method of improving a display of the LCD.

### (b) Description of the Related Art

A liquid crystal display ("LCD") is widely used as flat panel display including two panels provided with field-generating electrodes, such as pixel and common electrodes, and a liquid crystal ("LC") layer interposed there between. The LCD generates an electric field in the LC layer by applying voltages to the field-generating electrodes, and aligns the LC molecules of the LC layer to control the polarization of light incident thereto, thereby displaying the desired images.

In a vertically aligned ("VA") mode LCD, the directors of LC molecules are aligned vertically with respect to the upper and lower panels with no application of an electric field, as it gives a high contrast ratio and a wide reference viewing angle. The reference viewing angle refers to a viewing angle with a contrast ratio of 1:10, or an inter-gray luminance inversion limit angle.

With the VA mode LCD, cutouts or protrusions may be formed at the field-generating electrodes to realize a wide viewing angle. As the direction of the LC molecules to be inclined is determined by way of the cutouts or protrusions, the inclination directions of the LC molecules can be diversified, thereby widening the reference viewing angle.

However, the VA mode LCD involves poor visibility at the lateral side thereof, compared to the visibility at the front side thereof. For example, with the case of a patterned vertically aligned ("PVA") mode LCD having cutouts, the luminance thereof is heightened as it comes to the lateral side thereof, and in a serious case, the luminance difference between the high grays is eliminated so that the display image may appear to be distorted.

In order to enhance the lateral side visibility, it has been proposed that a pixel should be divided into two sub-pixels, which are capacitor-combined with each other. A voltage is directly applied to one of the sub-pixels, and a voltage drop is caused at the other sub-pixel due to the capacitor combination. In this way, the two sub-pixels are differentiated in voltage from each other and have different light transmittances.

However, with such a method, the transmittances of the two sub-pixels cannot be correctly controlled to the desired level, and in particular, the light transmittance is differentiated for the respective colors. Therefore, the voltages cannot be differently adjusted with respect to the respective colors. Furthermore, the aperture ratio is deteriorated due to the

addition of a conductor for a capacitor combination, and the light transmittance is reduced due to the capacitor combination-induced voltage drop.

## BRIEF SUMMARY OF THE INVENTION

The present invention provides a liquid crystal display ("LCD") improving lateral visibility without image deterioration or a decrease in aperture ratio, and a method of improving a display of the LCD.

Exemplary embodiments of the present invention provide a liquid crystal display including a first gate electrode formed on a substrate, a storage electrode formed on the substrate and separated from the first gate electrode, the storage electrode having a body and an extension, a gate insulating layer formed on the first gate electrode and the storage electrode, a first semiconductor formed on the gate insulating layer, a first source electrode formed on the first semiconductor, a first drain electrode formed on the first semiconductor, separated from the first source electrode, the first drain electrode having an end portion overlapping the first gate electrode, an expansion overlapping the body of the storage electrode and distanced from the end portion, and a connection connecting the end portion and the expansion, the connection overlapping the extension of the storage electrode, a passivation layer formed on the first source electrode and the first drain electrode and having a contact hole exposing the expansion of the first drain electrode, and a first field-generating electrode connected to the first drain electrode through the contact hole.

Other exemplary embodiments of the present invention provide a liquid crystal display including a plurality of pixels arranged in the form of a matrix, each pixel having first and second sub-pixels, a plurality of first signal lines connected to the first and second sub-pixels, a plurality of second signal lines intersecting the first signal lines and connected to the first sub-pixels, and a plurality of third signal lines intersecting the first signal lines and connected to the second sub-pixels. The first sub-pixels have first switching elements connected to the first and second signal lines, first liquid crystal capacitors connected to the first switching elements, and first storage capacitors connected to the first switching elements. The second sub-pixels have second switching elements connected to the first and third signal lines, second liquid crystal capacitors connected to the second switching elements, and second storage capacitors connected to the second switching elements. Voltages applied to the first and second liquid crystal capacitors are obtained from image information. The first sub-pixels are supplied with a voltage that is smaller than a voltage applied to the second sub-pixels with respect to a predetermined voltage. A storage capacitance of the first storage capacitors is larger than a first capacitance or a storage capacitance of the second storage capacitors is smaller than a second capacitance, where the first and second capacitances are capacitances of the first and second storage capacitors that cause kickback voltages of the first and second sub-pixels to be substantially equal to each other when the first and second sub-pixels are supplied with a same voltage.

Other exemplary embodiments of the present invention provide a liquid crystal display including a storage electrode formed on a substrate, the storage electrode having a body and an extension, and a first drain electrode having an end portion, an expansion overlapping the body of the storage electrode, and a connection connecting the end portion and the expansion, the connection overlapping the extension of the storage electrode.

Other exemplary embodiments of the present invention provide a method of improving a display of a liquid crystal

display, the method including adjusting capacitance of at least one storage capacitor within each pixel based on a capacitance variation of liquid crystal capacitors supplied with different data voltages in the liquid crystal display, wherein aperture ratio is not decreased by adjusting capacitance of at least one storage capacitor.

### BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more apparent by describing embodiments thereof in detail with reference to the accompanying drawings, in which:

FIGS. 1A to 1C are block diagrams of an exemplary LCD according to an exemplary embodiment of the present invention;

FIG. 2 is an equivalent circuit diagram of an exemplary pixel of the exemplary LCD shown in FIGS. 1A to 1C;

FIG. 3 is an equivalent circuit diagram of an exemplary sub-pixel of the exemplary LCD shown in FIGS. 1A to 1C;

FIG. 4 is a layout view of an exemplary TFT array panel for an exemplary LCD according to an exemplary embodiment of the present invention;

FIG. 5 is a layout view of an exemplary common electrode panel for an exemplary LCD according to an exemplary embodiment of the present invention;

FIG. 6 is a layout view of an exemplary LCD including the exemplary TFT array panel shown in FIG. 4 and the exemplary common electrode panel shown in FIG. 5;

FIGS. 7A and 7B are sectional views of the exemplary LCD shown in FIG. 6 taken along lines VIIA-VIIA, and VIIB-VIIB', VIIB'-VIIB'', respectively;

FIG. 8 is a layout view of an exemplary TFT array panel for another exemplary LCD according to an exemplary embodiment of the present invention;

FIG. 9 is a block diagram of an exemplary LCD according to another exemplary embodiment of the present invention;

FIG. 10 is an equivalent circuit diagram of an exemplary pixel of the exemplary LCD shown in FIG. 9;

FIG. 11 is a layout view of the exemplary LCD shown in FIG. 9;

FIG. 12 is a sectional view of the exemplary LCD shown in FIG. 11 taken along line XII-XII;

FIG. 13A is a layout view of an exemplary TFT array panel for an exemplary LCD according to another exemplary embodiment of the present invention;

FIG. 13B is a sectional view of the exemplary TFT array panel shown in FIG. 13A taken along line XIII-XIII;

FIG. 14A is a layout view of an exemplary TFT array panel for an exemplary LCD according to another exemplary embodiment of the present invention; and

FIG. 14B is a sectional view of the exemplary TFT array panel shown in FIG. 14A taken along line XIV-XIV.

### DETAILED DESCRIPTION OF THE INVENTION

The present invention will be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. The present invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein.

In the drawings, the thickness of layers, films, and regions are exaggerated for clarity. Like numerals refer to like elements throughout. 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.

As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

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.

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.

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.

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.

Now, LCDs according to exemplary embodiments of the present invention will be described with reference to FIGS. 1 to 3.

FIGS. 1A to 1C are block diagrams of an exemplary LCD according to an exemplary embodiment of the present invention, FIG. 2 is an equivalent circuit diagram of an exemplary pixel of the exemplary LCD shown in FIGS. 1A to 1C, and FIG. 3 is an equivalent circuit diagram of an exemplary sub-pixel of the exemplary LCD shown in FIGS. 1A to 1C.

As shown in FIGS. 1A to 1C, an LCD includes an LC panel assembly 300, a pair of gate drivers 400a and 400b, as shown in FIG. 1A, or a gate driver 400, as shown in FIGS. 1A and 1B, connected to the LC panel assembly 300, a data driver 500 connected to the LC panel assembly 300, a gray voltage

generator **800** connected to the data driver **500**, and a signal controller **600** for controlling the above-described elements.

The LC panel assembly **300**, as further shown in FIGS. **2** and **3**, includes a lower panel **100** also referred to as a TFT array panel, an upper panel **200** also referred to as a common electrode panel, and an LC layer **3** interposed there between, and it further includes a plurality of display signal lines  $G_1$  to  $G_n$  and  $D_1$  to  $D_m$  and a plurality of pixels PX connected thereto that are arranged substantially in a matrix format in a circuitual view.

The display signal lines  $G_{1a}$  to  $G_{nb}$  and  $D_1$  to  $D_m$  are provided on the lower panel **100** and include a plurality of gate lines  $G_{1a}$  to  $G_{nb}$  for transmitting gate signals (also called scanning signals) and a plurality of data lines  $D_1$  to  $D_m$  for transmitting data signals. The gate lines  $G_{1a}$  to  $G_{nb}$  extend substantially in a row direction, a first direction, and are substantially parallel to each other, while the data lines  $D_1$  to  $D_m$  extend substantially in a column direction, a second direction, and are substantially parallel to each other. The first direction is substantially perpendicular to the second direction.

FIG. **2** illustrates the display signal lines and an equivalent circuit at one pixel PX. The display signal lines include a pair of gate lines indicated by GLa and GLb, data lines indicated by DL, and a storage electrode line SL. The storage electrode line SL extends substantially parallel to and between the gate lines GLa and GLb.

Each pixel PX includes a pair of sub-pixels PXa and PXb, and the sub-pixels PXa and PXb include switching elements Qa and Qb, LC capacitors  $C_{LCa}$  and  $C_{LCb}$  connected to the switching elements Qa and Qb, and storage capacitors  $C_{STa}$  and  $C_{STb}$ , respectively. The storage capacitors  $C_{STa}$  and  $C_{STb}$  are connected to the switching elements Qa and Qb and the storage electrode line SL.

As shown in FIG. **3**, the switching element Q of the respective sub-pixels PXa and PXb such as a thin film transistor ("TFT") is provided on the lower panel **100**. The switching element Q has three terminals: a control terminal, such as a gate electrode, connected to the gate line GL; an input terminal, such as a source electrode, connected to the data line DL; and an output terminal, such as a drain electrode, connected to the LC capacitor  $C_{LC}$  and the storage capacitor  $C_{ST}$ .

The LC capacitor  $C_{LC}$  includes a sub-pixel electrode PE provided on the lower panel **100** and a common electrode CE provided on the upper panel **200**, as two terminals. The LC layer **3** disposed between the two electrodes PE and CE functions as a dielectric of the LC capacitor  $C_{LC}$ . The sub-pixel electrode PE is connected to the switching element Q, and the common electrode CE is supplied with a common voltage Vcom and covers the entire surface of, or at least substantially the entire surface of, the upper panel **200**. In an alternative embodiment, the common electrode CE may be provided on the lower panel **100**, and both electrodes PE and CE may have shapes of bars or stripes.

The storage capacitor  $C_{ST}$  is an auxiliary capacitor for the LC capacitor  $C_{LC}$ . The storage capacitor  $C_{ST}$  includes the sub-pixel electrode PE and the storage electrode line SL, which is provided on the lower panel **100**, overlaps the sub-pixel electrode PE via an insulator, and is supplied with a predetermined voltage such as the common voltage Vcom. Alternatively, the storage capacitor  $C_{ST}$  includes the sub-pixel electrode PE and an adjacent gate line called a previous gate line, which overlaps the sub-pixel electrode PE via an insulator.

For color display, each pixel uniquely represents one color out of a set of main colors (i.e., spatial division) or each pixel PX sequentially represents the colors in turn (i.e., temporal

division) such that a spatial or temporal sum of the colors is recognized as a desired color. An exemplary set of the main colors includes red, green, and blue colors, although other sets of colors would be within the scope of these embodiments. FIG. **3** shows an example of the spatial division in which each pixel PX includes a color filter CF representing one of the colors in an area of the upper panel **200**. Alternatively, the color filter CF is provided on or under the sub-pixel electrode PE on the lower panel **100**.

Referring to FIGS. **1A** to **1C**, the gate drivers **400a** and **400b** (or **400**) are connected to the gate lines  $G_{1a}$  to  $G_{nb}$  of the LC panel assembly **300**, and they synthesize the gate-on voltage Von and the gate-off voltage Voff to generate gate signals for application to the gate lines  $G_{1a}$  to  $G_{nb}$ .

As shown in FIG. **1A**, the pair of gate drivers **400a** and **400b** are respectively placed at left and right sides of the LC panel assembly **300**, and they are connected to the odd\_th and the even\_th gate lines  $G_{1a}$  to  $G_{nb}$ , respectively. Alternatively, as shown in FIGS. **1B** and **1C**, one gate driver **400** is placed at one side of the LC panel assembly **300**, and is connected to all the gate lines  $G_{1a}$  to  $G_{nb}$ . Although the gate driver **400** in FIGS. **1B** and **1C** is illustrated as disposed to the left of the LC panel assembly **300**, the gate driver **400** may alternatively be positioned on the right side of the LC panel assembly **300**. As shown in FIG. **1C**, two driving circuits **401** and **402** are built into the gate driver **400**, and are connected to the odd\_th and the even\_th gate lines  $G_{1a}$  to  $G_{nb}$ , respectively.

The gray voltage generator **800** generates two sets of a plurality of gray voltages (or reference gray voltages) related to the transmittance of the pixels PX. The two gray voltage sets are independently given to the two sub-pixels PXa and PXb forming each pixel PX. The voltages of each gray voltage set have a positive polarity with respect to the common voltage Vcom or a negative polarity with respect to the common voltage Vcom. Alternatively, only one (reference) gray voltage set may be generated instead of the two (reference) gray voltage sets.

The data driver **500** is connected to the data lines  $D_1$  to  $D_m$  of the LC panel assembly **300** to select one of the two gray voltage sets from the gray voltage generator **800**, and to apply one gray voltage of the selected gray voltage set to the pixel PX as a data voltage. However, in the case that the gray voltage generator **800** does not apply all the gray voltages but only applies the reference gray voltages, the data driver **500** divides the reference gray voltages and generates gray voltages with respect to all the grays while selecting the data voltages from the generated gray voltages.

The gate driver **400** of FIGS. **1B** and **1C** (or gate drivers **400a** and **400b** of FIG. **1A**) or the data driver **500** is directly mounted on the LC panel assembly **300** in the form of one or more driving integrated circuit ("IC") chips, or is mounted on a flexible printed circuit ("FPC") film (not shown) and attached to the LC panel assembly **300** in the form of a tape carrier package ("TCP"). By contrast, the gate driver **400** (or **400a** and **400b**) or the data driver **500** may be integrated with the LC panel assembly **300**.

The structure of an exemplary LCD according to an exemplary embodiment of the present invention will be described with reference to FIGS. **4** to **8**.

FIG. **4** is a layout view of an exemplary TFT array panel for an exemplary LCD according to an exemplary embodiment of the present invention, and FIG. **5** is a layout view of an exemplary common electrode panel for an exemplary LCD according to an exemplary embodiment of the present invention. FIG. **6** is a layout view of an exemplary LCD including the exemplary TFT array panel shown in FIG. **4** and the exemplary common electrode panel shown in FIG. **5**, FIGS.

7A and 7B are sectional views of the exemplary LCD shown in FIG. 6 taken along lines VIIA-VIIA, and VIIB-VIIB', VIIB'-VIIB'', respectively, and FIG. 8 is a layout view of an exemplary TFT array panel for another exemplary LCD according to an exemplary embodiment of the present invention.

As shown in FIGS. 4 to 7B, the LCD includes a TFT array panel 100, a common electrode panel 200 facing the TFT array panel 100, and an LC layer 3 disposed between the panels 100 and 200.

First, the TFT array panel 100 will be described with reference to FIGS. 4 and 6 to 7B.

A plurality of pairs of first and second gate lines 121a and 121b and a plurality of storage electrode lines 131 are formed on an insulating substrate 110 made of a material such as, but not limited to, transparent glass or plastic.

The first and second gate lines 121a and 121b transmit gate signals and extend substantially in a transverse direction, a first direction. The first and second gate lines 121a and 121b are arranged on the upper and lower parts of a pixel PX, respectively. That is, the first and second gate lines 121a and 121b flank the pixel PX.

Each of the first gate lines 121a includes a plurality of gate electrodes 124a projecting downward, towards the pixel PX to which it is connected, and an end portion 129a having a large area for contact with another layer or an external driving circuit. The end portion 129a is illustrated as arranged at the left side thereof.

Each of the second gate lines 121b includes a plurality of gate electrodes 124b projecting upward, towards the pixel PX to which it is connected, and an end portion 129b having a large area for contact with another layer or an external driving circuit. The end portion 129b is illustrated as arranged at the left side thereof.

Alternatively, the end portions 129a and 129b may be arranged both at the right side of the first and second gate lines 121a and 121b or may be arranged at opposite sides from each other.

A gate driving circuit, such as that contained within gate driver 400, or gate drivers 400a and 400b, for generating the gate signals may be mounted on an FPC film (not shown), which may be attached to the substrate 110, directly mounted on the substrate 110, or integrated with the substrate 110. The gate lines 121a and 121b may extend to be connected to a driving circuit that may be integrated on the substrate 110.

The storage electrode lines 131 are supplied with a predetermined voltage and extend substantially in a transverse direction, the first direction, parallel to the gate lines 121a and 121b.

Each storage electrode line 131 is disposed between two adjacent gate lines 121a and 121b, and may be positioned closer to the first gate line 121a than the second gate line 121b, and nearly equidistant from two adjacent second gate lines 121b. Each storage electrode line 131 includes a plurality of storage electrodes 137 expanding upward and downward, that is, expanding towards the first gate line 121a and towards the second gate line 121b, and a plurality of bar-shaped extensions 139 longitudinally extending upward from the storage electrodes 137, that is, extending towards the first gate line 121a.

The storage electrodes 137 are substantially rectangular-shaped to be symmetrical to the storage electrode lines 131, and the extensions 139 extend to near the right portion of the first gate electrodes 124a.

While a particular configuration is illustrated, it should be understood that the storage electrode lines 131 as well as the storage electrodes 137 and extensions 139 may have various shapes and arrangements.

The first and second gate lines 121a and 121b and the storage electrode lines 131 are preferably made of an aluminum Al-containing metal such as Al and an Al alloy, a silver Ag-containing metal such as Ag and a Ag alloy, a copper Cu-containing metal such as Cu and a Cu alloy, a molybdenum Mo-containing metal such as Mo and a Mo alloy, chromium Cr, tantalum Ta, or titanium Ti. However, they may have a multi-layered structure including two conductive films (not shown) having different physical characteristics. In such a multi-layered structured, one of the films is preferably made of a low resistivity metal including an Al-containing metal, a Ag-containing metal, or a Cu-containing metal for reducing signal delay or voltage drop, while another of the films is preferably made of a material such as a Mo-containing metal, Cr, Ta, or Ti, which has good physical, chemical, and electrical contact characteristics with other materials such as indium tin oxide ("ITO") or indium zinc oxide ("IZO"). Examples of the combination of two films include a lower Cr film and an upper Al (alloy) film and a lower Al (alloy) film and an upper Mo (alloy) film. While particular examples are described, the gate lines 121 and the storage electrode lines 131 may be made of various metals or conductors.

The lateral sides of the first and second gate lines 121a and 121b and the storage electrode lines 131 are inclined relative to a surface of the substrate 110, and the inclination angle thereof ranges from about 30 to about 80 degrees.

A gate insulating layer 140 preferably made of, but not limited to, silicon nitride (SiN<sub>x</sub>) or silicon oxide (SiO<sub>x</sub>) is formed on the first and second gate lines 121a and 121b and the storage electrode lines 131, as well as on exposed surfaces of the insulating substrate 110.

A plurality of semiconductor islands 154a, 154b, 156a, and 157a, preferably made of hydrogenated amorphous silicon ("a-Si") or polysilicon, are formed on the gate insulating layer 140. The semiconductor islands 154a and 154b are disposed on the gate electrodes 124a and 124b, respectively. The semiconductor islands 156a and 157a cover edges of the first and second gate lines 121a and 121b, the storage electrode lines 131, and the storage electrodes 137 and extensions 139.

A plurality of pairs of ohmic contact islands 163a, 163b, 165a, 165b, and 166a are formed on the semiconductor islands 154a, 154b, and 156a, and a plurality of pairs of ohmic contact islands (not shown) may be formed on the semiconductor islands 157a.

The ohmic contacts 163a, 163b, 165a, 165b, and 166a are preferably made of n+ hydrogenated a-Si heavily doped with an n-type impurity such as phosphorous, or they may be made of silicide. A pair of the first ohmic contacts 163a and 163b and a pair of the second ohmic contact 165a and 165b are placed on the semiconductors 154a and 154b, respectively.

The lateral sides of the semiconductor islands 154a, 154b, 156a, and 157a and the ohmic contacts 163a, 163b, 165a, 165b, and 166a are inclined relative to the surface of the substrate 110, and the inclination angles thereof are preferably in a range of about 30 to about 80 degrees.

A plurality of data lines 171 and a plurality of pairs of first and second drain electrodes 175a and 175b are formed on the ohmic contacts 163a, 163b, 165a, 165b, and 166a, and on the gate insulating layer 140.

The data lines 171 transmit data signals and extend substantially in the longitudinal direction, the second direction substantially perpendicular to the first direction, to intersect the gate lines 121a and 121b and the storage electrode lines

131. Each data line 171 includes a plurality of source electrodes 173a and 173b projecting toward the gate electrodes 124a and 124b, respectively, and an end portion 179 having a large area for contact with another layer or an external driving circuit. A data driving circuit, such as within data driver 500, for generating the data signals may be mounted on an FPC film (not shown), which may be attached to the substrate 110, directly mounted on the substrate 110, or integrated with the substrate 110. The data lines 171 may extend to be connected to a driving circuit that may be integrated with the substrate 110.

The first and second drain electrodes 175a and 175b are separated from each other and from the data lines 171.

Each of the first drain electrodes 175a includes bar-shaped end portions 176a facing the first source electrodes 173a with respect to the first gate electrodes 124a, wide rectangular-shaped expansions 177a opposite to the end portions 176a, and bar-shaped connections 176aa connecting the expansions 177a to the end portions 176a. The bar-shaped end portions 176a may extend substantially parallel to the gate line 121a, and the bar-shaped connection 176aa may extend substantially parallel to the data line 171.

Each expansion 177a overlaps the storage electrode 137, and each end portion 176a overlaps a first gate electrode 124a and is partly enclosed by a first source electrode 173a curved like a character C. The connection 176aa of the first drain electrode 175a is mainly disposed on the extension 139 to extend parallel to the extension 139 and is disposed within a vertical boundary of the extension 139. That is, the extension 139 may have a greater width than the connection 176aa.

Similar to the first drain electrodes 175a, each second drain electrode 175b includes bar-shaped end portions 176b facing the second source electrodes 173b overlapping the second gate electrodes 124b, wide rectangular-shaped expansions 177b opposite to the end portions 176b, and bar-shaped connections 176bb connecting the expansions 177b to the end portions 176b. Each expansion 177b overlaps the storage electrode 137 and the end portion 176b overlaps the second gate electrode 124b and are partly enclosed by a second source electrode 173b curved like a character C. The area of the expansion 177b of the second drain electrode 175b is smaller than the area of the expansion 177a of the first drain electrode 175a.

As described above, since the extension 139 is disposed under the connection 176aa of the first drain electrode 175a, storage capacitance of the storage electrode 137 is increased. Therefore, the size of the storage electrode 137 is made smaller to increase the aperture ratio.

The first and second gate electrodes 124a and 124b, the first and second source electrodes 173a and 173b, and the first and second drain electrodes 175a and 175b along with the semiconductors 154a and 154b form first and second TFTs Qa and Qb having channels formed on the semiconductor islands 154a and 154b disposed between the source electrodes 173a and 173b and the drain electrodes 175a and 175b, respectively.

The data lines 171 and the drain electrodes 175a and 175b are preferably made of a refractory metal such as Cr, Mo, Ta, Ti, or alloys thereof. Alternatively, they may have a multilayered structure including a refractory metal film (not shown) and a low resistivity film (not shown). Examples of such a multi-layered structure include a double-layered structure including a lower Cr/Mo (alloy) film and an upper Al (alloy) film and a triple-layered structure of a lower Mo (alloy) film, an intermediate Al (alloy) film, and an upper Mo (alloy) film.

While particular embodiments are described, the data lines 171 and the drain electrodes 175a and 175b may be made of various metals or conductors.

The data lines 171 and the drain electrodes 175a and 175b have inclined edge profiles, and the inclination angles thereof ranges from about 30 to about 80 degrees.

The ohmic contacts 163a, 163b, 165a, 165b, and 166a are interposed only between the underlying semiconductors 154a and 154b and the overlying data lines 171 and drain electrodes 175a and 175b thereon, and reduce the contact resistance there between. The semiconductors 156a and 157a disposed on the gate lines 121a and 121b and storage electrode lines 131 smooth the profile of the surface, thereby preventing the disconnection of the data lines 171 and the drain electrodes 175a and 175b. The semiconductor islands 154a and 154b include some exposed portions that are not covered with the data lines 171 and the drain electrodes 175a and 175b, such as portions located between the source electrodes 173a and 173b and the drain electrodes 175a and 175b, respectively, that form channels of the first and second TFTs Qa and Qb.

A passivation layer 180 is formed on the data lines 171 and the drain electrodes 175a and 175b and the exposed portions of the semiconductor islands 154a and 154b, as well as on any exposed portions of the gate insulating layer 140. The passivation layer 180 is preferably made of an inorganic or organic insulator and it may have a flat top surface. Examples of the inorganic insulator include, but are not limited to, silicon nitride and silicon oxide. The organic insulator may have photosensitivity and a dielectric constant of less than about 4.0. Although illustrated as a single layer, the passivation layer 180 may alternatively include a lower film of an inorganic insulator and an upper film of an organic insulator such that it takes the excellent insulating characteristics of the organic insulator while preventing the exposed portions of the semiconductor islands 154a and 154b from being damaged by the organic insulator.

The passivation layer 180 has a plurality of contact holes 182, 185a, and 185b exposing the end portions 179 of the data lines 171 and the expansions 177a and 177b of the first and second drain electrodes 175a and 175b, respectively. The passivation layer 180 and the gate insulating layer 140 have a plurality of contact holes 181a and 181b exposing the end portions 129a and 129b of the first and second gate lines 121a and 121b.

A plurality of pixel electrodes 191 each having first and second sub-pixel electrodes 191a and 191b, a plurality of shield electrodes 88, and a plurality of contact assistants 81a, 81b, and 82 are formed on the passivation layer 180, such as during a same manufacturing process. They are preferably made of a transparent conductor such as ITO and IZO, or a reflective conductor such as Ag, Al, Cr, and alloys thereof.

Each pixel electrode 191 approximates a rectangle that has four chamfered corners. The chamfered corners of the pixel electrode 191 make an angle of about 45 degrees with respect to the gate lines 121a and 121b.

A pair of sub-pixel electrodes 191a and 191b forming a pixel electrode 191 engage with each other with respect to a gap 92. The second sub-pixel electrode 191b is approximately a rotated equilateral trapezoid, the base thereof being dented, such as at a location of the storage electrode line 131, and is mainly surrounded by the first sub-pixel electrode 191a. The first sub-pixel electrode 191a has an upper trapezoid, a lower trapezoid, and a center trapezoid connected to each other at a left side of the pixel.

The first sub-pixel electrode 191a has cutouts 93a to 93c and 94a to 94c extending from the top side of the upper

trapezoid and the bottom side of the lower trapezoid to each right side thereof, respectively. The first gate line **121a** extends between the cutout **93a** and the cutout **93b** and between the cutout **94a** and the cutout **94b**. The center trapezoid of the first sub-pixel electrode **191a** is fitted into the 5 dented base of the second sub-pixel electrode **191b**. The first sub-pixel electrode **191a** includes a center cutout **91** that includes a transverse portion and a pair of oblique portions connected thereto. The transverse portion extends shortly along an imaginary center transverse line of the first sub-pixel electrode **191a**, and the oblique portions extend from an end of the transverse portion to the left edge of the pixel electrode **191**. The oblique portions make an angle of about 45 degrees with respect to the storage electrode line **131**.

The gap **92** between the first sub-pixel electrode **191a** and the second sub-pixel electrode **191b** includes two pairs of upper and lower oblique portions and three longitudinal portions. The upper and lower oblique portions make an angle of about 45 degrees with respect to the gate lines **121a** and **121b**, respectively. For explanatory convenience, the gap **92** will also be referred to as a cutout. The cutouts **91** to **94c** substantially have inversion symmetry with respect to the storage electrode line **131**. The cutouts **91** to **94c** make an angle of about 45 degrees with the gate lines **121a** and **121b**, and the cutouts between the first gate line **121a** and the storage electrode line **131** extend substantially perpendicular to the cutouts between the storage electrode line **131** and the second gate line **121b**. The pixel electrode **191** is partitioned into a plurality of partitions by the cutouts **92**, **93a** to **93c**, and **94a** to **94c**. Accordingly, the pixel electrode **191** is horizontally bisected around the storage electrode line **131**, and the upper half and the lower half of the pixel electrode **191** are partitioned into six partitions by the cutouts **91** to **94c**, respectively.

While a particular embodiment of sub-pixel electrodes **191a** and **191b** and cutouts **91** to **94c** is illustrated and described, the number of partitions or the number of the cutouts may alternatively be varied depending on design factors such as the size of pixels, the ratio of the transverse edges and the longitudinal edges of the pixel electrode **191**, the type and characteristics of the liquid crystal layer **3**, and so on.

The first and second sub-pixel electrodes **191a** and **191b** are physically and electrically connected to the first and second drain electrodes **175a** and **175b** through the contact holes **185a** and **185b** such that the first and second sub-pixel electrodes **191a** and **191b** receive data voltages from the first and second drain electrodes **175a** and **175b** via their expansions **177a** and **177b**, respectively. A pair of the sub-pixel electrodes **191a** and **191b** are supplied with different data voltages that are predetermined based on an input image signal, respectively, and the magnitudes of the data voltages may be determined depending upon the sizes and shape of the sub-pixel electrodes **191a** and **191b**. Furthermore, the areas of the sub-pixel electrodes **191a** and **191b** may differ from each other. For instance, the second sub-pixel electrode **191b** receives a voltage that is higher than that of the first sub-pixel electrode **191a**, and the second sub-pixel electrode **191b** is smaller in area than the first sub-pixel electrode **191a**.

The sub-pixel electrodes **191a** and **191b** that are supplied with the data voltages and the common electrode **270** of the common electrode panel **200** that is supplied with a common voltage form capacitors  $C_{LCa}$  and  $C_{LCb}$  that are referred to as "liquid crystal capacitors," ("LC capacitors") which store applied voltages after the TFT turns off. Each of the LC capacitors  $C_{LCa}$  and  $C_{LCb}$  includes the LC layer **3** as a dielectric.

The first and second sub-pixel electrodes **191a** and **191b** and the expansions **177a** and **177b** connected thereto overlap a storage electrode line **131** including a storage electrode **137** and an extension **139**. The first and second sub-pixel electrodes **191a** and **191b** and the expansions **177a** and **177b** connected thereto and the storage electrode line **131** form additional capacitors  $C_{STa}$  and  $C_{STb}$  referred to as "storage capacitors," which enhance the voltage storing capacity of the LC capacitors  $C_{LCa}$  and  $C_{LCb}$ , respectively.

The shielding electrode **88** of each pixel is supplied with the common voltage, and it includes longitudinal portions extending along the data lines **171** and transverse portions extending along the second gate lines **121b**. The longitudinal portions fully cover the data lines **171**, and the transverse portions lie within the boundary of the second gate lines **121b**. The shielding electrodes **88** block electric fields that are generated between the data lines **171** and the pixel electrodes **191** and between the data lines **171** and the common electrode **270** to reduce the distortion of the voltage of the pixel electrode **191** and the signal delay of the data voltages transmitted by the data lines **171**. If necessary, the shielding electrode **88** may be omitted.

The contact assistants **81a**, **81b**, and **82** are connected to the end portions **129a** and **129b** of the gate lines **121a** and **121b** and the end portions **179** of the data lines **171** through the contact holes **181a**, **181b**, and **182**, respectively. The contact assistants **81a**, **81b**, and **82** protect the end portions **129a**, **129b**, and **179** and enhance the adhesion between the end portions **129a**, **129b**, and **179**, and external devices.

A description of the common electrode panel **200** follows with reference to FIGS. **5** to **7B**.

A light blocking member **220**, referred to as a black matrix, for preventing light leakage is formed on an insulating substrate **210** made of a material such as, but not limited to, transparent glass or plastic.

The light blocking member **220** has a plurality of openings **225** that face the pixel electrodes **191**, and it may have substantially the same planar shape as the pixel electrodes **191**. Otherwise, the light blocking member **220** may include a plurality of rectilinear portions facing the data lines **171** on the TFT array panel **100** and a plurality of widened portions facing the TFTs **Qa** and **Qb** on the TFT array panel **100**. However, the light blocking member **220** may be formed with various shapes for preventing light leakage near the pixel electrodes **191** and the TFTs **Qa** and **Qb**.

A plurality of color filters **230** are also formed on the substrate **210**, and they are disposed substantially within the areas enclosed by the light blocking member **220**. The color filters **230** may extend substantially in the longitudinal direction along the pixel electrodes **191**. The color filters **230** may represent one of three colors such as, but not limited to, red, green, and blue colors.

An overcoat **250** is formed on the color filters **230** and the light blocking member **220**. The overcoat **250** is preferably made of an (organic) insulator, and it prevents the color filters **230** from being exposed and provides a flat surface. In an alternative embodiment, the overcoat **250** may be omitted.

A common electrode **270** is formed on the overcoat **250**. The common electrode **270** is preferably made of a transparent conductive material such as, but not limited to, ITO and IZO, and has a plurality of sets of cutouts, such as cutouts **71**, **72**, **73**, **74a**, **74b**, **75a**, **75b**, **76a**, and **76b**.

A set of cutouts **71** to **76b** face a pixel electrode **191** and include center cutouts **71** to **73**, upper cutouts **74a**, **75a**, and **76a**, and lower cutouts **74b**, **75b**, and **76b**. Each of the cutouts **71** to **76b** within one set of cutouts **71** to **76b** is disposed on the common electrode **270** at a location corresponding to loca-

tions between adjacent cutouts **91** to **94c** of the pixel electrode **191**, between a cutout **91**, **94a**, **94b**, or **94c** and a chamfered edge of the pixel electrode **191**, or between left edges of the pixel electrodes **191**. In addition, each of the cutouts **71** to **76b** has at least an oblique portion extending parallel to the cutout **91** to **94c** of the pixel electrode **191**.

Each of the lower and the upper cutouts **74a** to **76b** includes an oblique portion, and a pair of transverse and longitudinal portions or a pair of longitudinal portions. The oblique portion extends approximately from a right edge to an upper edge or lower edge of the pixel electrodes and parallel to the upper and lower cutouts **93a** to **94c** of the pixel electrodes **191**. The transverse and longitudinal portions extend from respective ends of the oblique portions corresponding to locations along edges of the pixel electrodes **191**, overlapping the edges thereof, and making obtuse angles with the oblique portion.

Each of the center cutouts **71** and **72** includes a central transverse portion, a pair of oblique portions, and a pair of terminal longitudinal portions. The central transverse portion extends on the common electrode **270** at a location approximately corresponding from a center or the right edge of the pixel electrode **191** along the storage electrode line **131**. The oblique portions extend from an end of the central transverse portion approximately to locations corresponding to the left edge of the pixel electrode **191** and approximately parallel to the respective lower and upper cutouts **74a** to **76a**. The terminal longitudinal portions extend from the ends of the respective oblique portions corresponding to locations along the left edge of the pixel electrode **191**, overlapping the left edge of the pixel electrode **191**, and making obtuse angles with the respective oblique portions.

As illustrated, the oblique portions of the cutouts **73** to **76b** include triangular-shaped notches.

The notches may be formed in the shape of a rectangle, a trapezoid, or a semi-circle, or they may be concave or convex. The notches determine the tilt directions of LC molecules of the LC layer **3** located at the regional boundary corresponding to the cutouts **71** to **76b**.

The set of cutouts **71** to **76b** may be repeated across the common electrode **270** at locations corresponding to locations of pixel electrodes **191**.

While a particular arrangement of one set of cutouts **71** to **76b** has been illustrated and described, the number and the arrangements of the cutouts **71** to **76b** may alternatively be varied depending on design factors, and the light blocking member **220** may overlap the cutouts **71** to **76b** to block the light leakage through the cutouts **71** to **76b**.

Alignment layers **11** and **21** that may be homeotropic are coated on inner surfaces of the panels **100** and **200**, and polarizers **12** and **22** are provided on outer surfaces of the panels **100** and **200** so that their polarization axes may be crossed and one of the polarization axes may be parallel to the gate lines **121a** and **121b**. One of the polarizers **12** and **22** may be omitted when the LCD is a reflective LCD.

The LCD may further include at least one retardation film (not shown) for compensating the retardation of the LC layer **3**. The retardation film has birefringence and retards opposite to the LC layer **3**.

It is preferable that the LC layer **3** has negative dielectric anisotropy and that it is subjected to a vertical alignment such that the LC molecules in the LC layer **3** are aligned with their long axes substantially vertical to the surfaces of the panels **100** and **200** in the absence of an electric field. Accordingly, incident light cannot pass through the crossed polarization system **12** and **22**.

Upon application of the common voltage to the common electrode **270** and a data voltage to a pixel electrode **191**,

voltage differences across the LC capacitors  $C_{LCa}$  and  $C_{LCb}$  are generated and thereby an electric field that is substantially perpendicular to the surfaces of the panels **100** and **200** is generated. Both the pixel electrode **191** and the common electrode **270** are commonly referred to as “field-generating electrodes” hereinafter. The LC molecules tend to vary their tilt directions and change their orientations in response to the electric field such that their long axes are perpendicular to the field direction and a variation amount of polarization of incident light is varied depending upon the orientations of the LC molecules in the LC layer **3**. The polarization variation causes a transmittance variation by the polarizers **12** and **22** and thereby an image is represented on the LCD.

Tilt angles of the LC molecules are varied based on the strength of the electric field. When the voltage applied to the first sub-pixel electrode **191a** is smaller than that applied to the second sub-pixel electrode **191b**, a voltage  $V_a$  across the first LC capacitor  $C_{LCa}$  is larger than a voltage  $V_b$  across the second LC capacitor  $C_{LCb}$  so that the tilt angles of LC molecules in a first sub-pixel **PXa** and a second sub-pixel **PXb** are different from each other, and thereby luminance of the sub-pixels **PXa** and **PXb** differ from each other. Accordingly, when the voltages  $V_a$  and  $V_b$  for the LC capacitor  $C_{LCa}$  and  $C_{LCb}$  are suitably adjusted, an image viewed at a lateral side becomes close to that viewed at a front side, thereby enhancing lateral visibility of the LCD.

The tilt directions of the LC molecules are determined by horizontal components caused by distortion of the electric field generated by the oblique edges of the cutouts **71** to **76b** and **91** to **94c** and the pixel electrodes **191**, and the horizontal components are perpendicular to edges of the cutouts **71** to **76b** and **91** to **94c** and edges of the pixel electrodes **191**.

Referring to FIG. **6**, a set of the cutouts **71** to **76b** or **91** to **94c** divides a pixel electrode **171** into a plurality of sub-areas, and each sub-area has two major edges making oblique angles with the major edges of the pixel electrode **191**. Tilt directions of the LC molecules of the respective sub-areas are determined based on the directions defined by horizontal components of the electric field, and the tilt directions generally have four directions, thereby increasing the reference viewing angle of the LCD.

While exemplary embodiments of the cutouts **71** to **76b** and **91** to **94c** are illustrated and described, the shapes and the arrangements of the cutouts **71** to **76b** and **91** to **94c** may be modified in alternative embodiments.

In an alternative embodiment, at least one of the cutouts **71** to **76b** and **91** to **94c** can be substituted with protrusions (not shown) or depressions (not shown). The protrusions are preferably made of an organic or inorganic material and disposed on or under the field-generating electrodes **191** or **270**.

Next, the operation of the above-described LCD will be described with reference to FIGS. **1A** and **2**.

The signal controller **600** is supplied with input image signals R, G, and B and input control signals for controlling the display thereof from an external graphics controller (not shown). The input image signals R, G, and B contain luminance information of each pixel **PX**, and the luminance has a predetermined number of grays, for example  $1024(=2^{10})$ ,  $256(=2^8)$  or  $64(=2^6)$  grays. The input control signals include a vertical synchronization signal  $V_{sync}$ , a horizontal synchronization signal  $H_{sync}$ , a main clock signal  $MCLK$ , a data enable signal  $DE$ , etc.

After generating gate control signals  $CONT1$  and data control signals  $CONT2$  and processing the image signals R, G, and B to be suitable for the operation of the LC panel assembly **300** on the basis of the input control signals and the input image signals R, G, and B, the signal controller **600**

transmits the gate control signals CONT1 to the gate drivers **400a** and **400b**, and the processed image signals DAT and the data control signals CONT2 to the data driver **500**.

The gate control signals CONT1 include a scanning start signal STV for instructing to start scanning and at least a clock signal for controlling the output time of the gate-on voltage Von.

The data control signals CONT2 include a horizontal synchronization start signal STH for informing of start of data transmission for a group of sub-pixels PXa and PXb in each pixel PX, a load signal LOAD for instructing to apply the data voltages to the data lines D<sub>1</sub> to D<sub>m</sub>, and a data clock signal HCLK. The data control signals CONT2 may further include an inversion signal RVS for reversing the polarity of the data voltages (with respect to the common voltage Vcom).

In response to the data control signals CONT2 from the signal controller **600**, the data driver **500** receives a packet of the image data DAT for the group of sub-pixels PXa and PXb from the signal controller **600** and receives one of the two sets of gray voltages supplied from the gray voltage generator **800**. The data driver **500** converts the image data DAT into analog data voltages selected from the gray voltages supplied from the gray voltage generator **800**, and applies the data voltages to the data lines D<sub>1</sub> to D<sub>m</sub>.

Alternatively, a separately provided external selection circuit (not shown) rather than the data driver **500** may select and transmit one of the two groups of gray voltages to the data driver **500**, or the gray voltage generator **800** may supply reference voltages having varying magnitudes and that are divided by the data driver **500** to form gray voltages.

The gate drivers **400a** and **400b** apply the gate-on voltage Von to the gate lines G<sub>1a</sub> to G<sub>nb</sub> in response to the gate control signals CONT1 from the signal controller **600**, thereby turning on the switching elements Qa and Qb connected thereto. The data voltages from the data driver **500** applied to the data lines D<sub>1</sub> to D<sub>m</sub> are supplied to the sub-pixels PXa and PXb through the activated switching elements Qa and Qb.

The difference between the data voltage applied to the sub-pixels PXa and PXb and the common voltage Vcom is represented as a voltage across the LC capacitor C<sub>LCa</sub> and C<sub>LCb</sub>, which is referred to as a pixel voltage. The LC molecules in the LC capacitor C<sub>LCa</sub> and C<sub>LCb</sub> have orientations depending on the magnitude of the pixel voltage, and the molecular orientations determine the polarization of light passing through the LC layer **3**. The polarizers **12** and/or **22** convert the light polarization into the light transmittance such that the pixels PX display the luminance represented by the image data DAT.

The above-described two groups of gray voltages show two different gamma curves. Since the two groups are supplied with the two sub-pixels PXa and PXb of a pixel PX, the synthesis of the two gamma curves forms a gamma curve for a pixel PX. The two groups of the gray voltages are preferably determined such that the synthesized gamma curve approaches a reference gamma curve at a front view. For example, the synthesized gamma curve at a front view coincides with the most suitable reference gamma curve at a front view, and the synthesized gamma curve at a lateral view is the most similar to the reference gamma curve at a front view. Therefore, the lateral visibility may be improved.

As described above, since the area of the second sub-pixel electrode **191b** which is supplied with a larger voltage than the first sub-pixel electrode **191a** is smaller than the area of the first sub-pixel electrode **191a**, the distortion of the lateral visibility is decreased. In particular, when the area ratio of the first sub-pixel electrode **191a** and the second sub-pixel elec-

trode **191b** is about 2:1, the latter gamma curve closely approaches the front gamma curve, thereby much improving the lateral visibility.

By repeating this procedure by a unit of half of a horizontal period (which is denoted by "1/2H" and is equal to half a period of the horizontal synchronization signal Hsync or the data enable signal DE), all gate lines G<sub>1a</sub> to G<sub>nb</sub> are sequentially supplied with the gate-on voltage Von during a frame, thereby applying the data voltages to all pixels.

When the next frame starts after one frame finishes, the inversion control signal RVS applied to the data driver **500** is controlled such that the polarity of the data voltages is reversed (which is referred to as "frame inversion"). The inversion control signal RVS may also be controlled such that the polarity of the image data signals flowing in a data line are periodically reversed during one frame (for example, row inversion and dot inversion), or the polarity of the image data signals in one packet are reversed (for example, column inversion and dot inversion).

Meanwhile, with reference to FIG. **3**, a kickback voltage Vk defined below is generated by parasitic capacitance Cgd between the control terminal (gate electrode) and output terminal (drain electrode) of the switching element Q when a state of the gate signal is changed from the gate-on voltage Von into the gate-off voltage Voff and causes a decrease of a voltage applied to the pixel electrode PE.

$$Vk = [Cgd / (C_{LC} + C_{ST} + Cgd)] \times \Delta Vg$$

Here, ΔVg is a difference voltage between the gate-on voltage Von and the gate-off voltage Voff.

As will be further described below, the magnitudes of the kickback voltages Vka and Vkb of the first and second sub-pixels PXa and PXb of the LCD according to the exemplary embodiments of the present invention are substantially equal to each other.

The capacitance of the LC capacitors C<sub>LCa</sub> and C<sub>LCb</sub> of the first and second sub-pixels PXa and PXb is defined by the areas of the first and second sub-pixel electrodes **191a** and **191b**. For example, the first sub-pixel electrode **191a** may have a larger area than the second sub-pixel electrode **191b**. Therefore, when the magnitudes of the voltages applied to the first and second sub-pixel electrodes **191a** and **191b** are substantially equal to each other, the capacitance of the first LC capacitor C<sub>oc,a</sub> is larger than that of the second LC capacitor C<sub>LCb</sub>. In addition, the area of the expansion **177a** of the first drain electrode **175a** overlapping the storage electrode **137** is larger than the area of the expansion **177b** of the second drain electrode **175b**. However, the first LC capacitor C<sub>oc,a</sub> of the first sub-pixel electrode **191a** mostly operating at low grays has a lower dielectric constant that is defined by the orientation of the LC molecules than that of the second LC capacitor C<sub>LCb</sub> of the second sub-pixel electrode **191b** mostly operating at upper grays, so that the capacitance of the first LC capacitor C<sub>LCa</sub> is decreased and the capacitance of the second LC capacitor C<sub>LCb</sub> is increased.

Accordingly, when the capacitance of the LC capacitors C<sub>LCa</sub> and C<sub>LCb</sub> of the first and second sub-pixel electrodes **191a** and **191b** is fixed, the magnitude of the kickback voltage Vka of the first sub-pixel electrode **191a** is larger than the magnitude of the kickback voltage Vkb of the second sub-pixel electrode **191b**. As a result, for equilibrating the kickback voltages Vka and Vkb, the capacitance of the first and second storage capacitors C<sub>STa</sub> and C<sub>STb</sub> should be adjusted.

To increase the capacitance of the storage capacitor C<sub>STa</sub> for preventing increments of the kickback voltage Vka, the extension **139** of the storage electrode **137** that is overlapped by the connection **176aa** of the first drain electrode **175a**

should be further formed or the vertical width of the expansion **177a** of the first drain electrode **175** and the storage electrode **137** overlapped by the expansion **177a** should be enlarged. Since the magnitudes of the kickback voltages  $V_{ka}$  and  $V_{kb}$  of the first and second sub-pixels **PXa** and **PXb** are substantially equal to each other, the optimal magnitude of the common voltage  $V_{com}$  is defined and the kickback voltages  $V_{ka}$  and  $V_{kb}$  also equilibrate, and thereby a flicker phenomenon is prevented.

As shown in FIGS. **4** to **7**, the storage capacitor  $C_{STa}$  is further formed by the extension **139** of the storage electrode **137** overlapped by the connection **176aa** of the first drain electrode **175a**, so that sufficient storage capacitance of the storage capacitor  $C_{STa}$  is ensured even though the area of the storage electrode **137** is decreased, and the aperture ratio also increases since the area of the storage electrode **137** overlapped by the expansion **177a** need not be enlarged.

In addition, by adjusting the areas of the first and second drain electrodes **175a** and **175b** overlapping the storage electrode **137** and its extension **139**, the capacitance of the first and second storage capacitors  $C_{STa}$  and  $C_{STb}$  may be defined so that the kickback voltages  $V_{ka}$  and  $V_{kb}$  thereof are equal to each other. Furthermore, the gate signals applied to the first and second sub-pixels **PXa** and **PXb** via the first and second gate lines **121a** and **121b** may be different. For an example, the  $\Delta V_g$  may be adjusted by changing the magnitude of the gate-on voltage  $V_{on}$ , thereby making the magnitudes of the kickback voltages  $V_{ka}$  and  $V_{kb}$  equal.

Since the common electrode **270** and the shielding electrodes **88** are supplied with the same common voltage  $V_{com}$ , almost no electric field is generated there between. Therefore, the LC molecules disposed between the common electrode **270** and the shielding electrodes **88** have a maintained initial vertical alignment state, thereby blocking incident light.

Next, another exemplary LCD according to the exemplary embodiments of the present invention will be described with reference to FIG. **8**.

FIG. **8** is a layout view of an exemplary TFT array panel for another exemplary LCD according to an exemplary embodiment of the present invention.

Referring to FIG. **8**, layered structures of the TFT array panel of the LCD shown in FIG. **8** are substantially the same as those shown in FIG. **4**, and therefore further reference may be made to the description of FIG. **4** for like elements.

A plurality of first and second gate lines **121a** and **121b** including first and second gate electrodes **124a** and **124b** and end portions **129a** and **129b** and a plurality of storage electrode lines **131** including storage electrodes **137** and extensions **139** are formed on an insulating substrate **110**. A gate insulating layer **140**, a plurality of semiconductor islands **154a**, **154b**, **157a**, and a plurality of ohmic contact islands (not shown) are sequentially formed on the gate lines **121a** and **121b** and the storage electrode lines **131**. A plurality of data lines **171**, each including source electrodes **173a** and **173b** and end portions **179**, and a plurality of drain electrodes **175a** and **175b** including expansions **177a** and **177b**, end portions **176a** and **176b**, and connections **176aa** and **176bb** are formed on the ohmic contacts and the gate insulating layer **140**. A passivation layer **180** is formed on the data lines **171**, the drain electrodes **175a** and **175b**, and the exposed portions of the semiconductors **154a** and **154b**. A plurality of contact holes **181a**, **181b**, **182**, **185a**, and **185b** are provided at the passivation layer **180** and the gate insulating layer **140**. A plurality of pixel electrodes **191**, a plurality of shielding electrodes **88**, and a plurality of contact assistants **81a**, **81b**, and **82** are formed on the passivation layer **180**.

Differing from the TFT array panel shown in FIG. **4**, the widths of the expansion **177b** of the second drain electrode **175b** and the portion of the storage electrode **137** overlapped by the expansion **177b**, located on a right side of each pixel **PX**, are narrower than those shown in FIG. **4**. Therefore, when the first sub-pixel electrode **191a** is supplied with a lower voltage than the second sub-pixel electrode **191b**, the capacitance of the second LC capacitor  $C_{LCb}$  increases to prevent the kickback voltage  $V_{kb}$  from becoming smaller than the kickback voltage  $V_{ka}$ . Accordingly, the magnitudes of the kickback voltages  $V_{ka}$  and  $V_{kb}$  substantially become equal to each other, and thereby the optimal common voltage  $V_{com}$  may be defined and the magnitudes of the kickback voltages  $V_{ka}$  and  $V_{kb}$  may be equilibrated, thus preventing the flicker phenomenon and the decrease of the aperture ratio.

Various characteristics based on the TFT array panel shown in FIG. **4** may be applied to the TFT array panel shown in FIG. **8**.

Next, an exemplary LCD according to another exemplary embodiment of the present invention will be described with reference to FIGS. **9** and **10**.

FIG. **9** is a block diagram of an exemplary LCD according to another exemplary embodiment of the present invention, and FIG. **10** is an equivalent circuit diagram of an exemplary pixel of the exemplary LCD shown in FIG. **9**.

Referring to FIG. **9**, an LCD includes an LC panel assembly **301**, a gate driver **403** and a data driver **501** that are connected to the LC panel assembly **301**, a gray voltage generator **801** that is connected to the data driver **500**, and a signal controller **601** for controlling the above elements.

Referring to FIG. **9**, the LC panel assembly **301** includes a plurality of signal lines  $G_1$  to  $G_n$  and  $D_1$  to  $D_{2m}$ , and a plurality of pixels **PX** connected thereto and arranged substantially in a matrix.

The signal lines  $G_1$  to  $G_n$  and  $D_1$  to  $D_{2m}$  include a plurality of gate lines  $G_1$  to  $G_n$  for transmitting gate signals (also referred to as "scanning signals"), and a plurality of data lines  $D_1$  to  $D_{2m}$  for transmitting data signals. The gate lines  $G_1$  to  $G_n$  extend substantially in a row direction, a first direction, and substantially parallel to each other, while the data lines  $D_1$  to  $D_{2m}$  extend substantially in a column direction, a second direction, and substantially parallel to each other. The first direction may be substantially perpendicular to the second direction. A pair of data lines from the set of data lines  $D_1$  to  $D_{2m}$  is disposed on opposite sides of each pixel **PX**, respectively. The signal lines may further include a plurality of storage lines **SL** extending substantially parallel to the gate lines  $G_1$  to  $G_n$ .

FIG. **10** illustrates the display signal lines and an equivalent circuit at one pixel **PX**. The display signal lines include a gate line indicated by **GL**, a pair of data lines indicated by **DLa** and **DLb**, and a storage electrode line **SL**. The storage electrode line **SL** extends substantially parallel to the gate line **GL**.

Each pixel **PX** includes a pair of sub-pixels **PXc** and **PXd**, and the sub-pixels **PXc**/**PXd** include switching elements **Qc**/**Qd** that are connected to the gate line **GL** and the data lines **DLa**/**DLb**, LC capacitors  $C_{LCc}$ / $C_{LCd}$  that are connected to the switching elements **Qc**/**Qd**, and storage capacitors  $C_{STc}$ / $C_{STd}$ , respectively. The storage capacitors  $C_{STc}$ / $C_{STd}$  are connected to the switching elements **Qc**/**Qd** and the storage electrode line **SL**.

The switching elements **Qc**/**Qd** have input terminals that are connected to the data lines **DLa**/**DLb**, respectively, and each have a control terminal that is connected to the gate line **GL**. Otherwise, each sub-pixel **PXc** and **PXd** is substantially the same as that shown in FIG. **3**, and detail descriptions of the sub-pixels **PXc** and **PXd** are omitted.

The gray voltage generator **801** generates two sets of a plurality of gray voltages related to the transmittance of the sub-pixels PXc and PXd. The voltages in one set have a positive polarity with respect to the common voltage Vcom, while those in the other set have a negative polarity with respect to the common voltage Vcom.

The gate driver **403** is connected to the gate lines  $G_1$  to  $G_n$  of the LC panel assembly **301**, and synthesizes the gate-on voltage Von and the gate-off voltage Voff to generate gate signals for application to the gate lines  $G_1$  to  $G_n$ .

The data driver **501** is connected to the data lines  $D_1$  to  $D_{2m}$  of the LC panel assembly **301**, and applies data voltages selected from the gray voltages supplied from the gray voltage generator **801** to the sub-pixels PXc and PXd through the data lines  $D_1$  to  $D_{2m}$ .

The signal controller **601** controls the gate driver **403** and the data driver **501**.

The structure of the exemplary LCD according to the exemplary embodiment of the present invention shown in FIGS. **9** and **10** will be further described with reference to FIGS. **11** to **12**.

FIG. **11** is a layout view of the exemplary LCD shown in FIG. **9**, and FIG. **12** is a sectional view of the exemplary LCD shown in FIG. **11** taken along line XII-XII.

As shown in FIGS. **11** to **12**, the LCD includes a TFT array panel **101**, a common electrode panel **201** facing the TFT array panel **101**, and a liquid crystal layer **3** disposed between the panels **101** and **201**.

First, the TFT array panel **101** will be described.

A plurality of gate lines **121** and a plurality of storage electrode lines **131a** are formed on an insulating substrate **110** made of a material such as, but not limited to, transparent glass or plastic.

The gate lines **121** transmit gate signals and extend substantially in a transverse direction, the first direction. Each of the gate lines **121** includes a plurality of first and second gate electrodes **124c** and **124d** projecting upward, towards the pixel PX to which they are associated, and an end portion **129** having a large area for contact with another layer or an external driving circuit, such as the gate driver **403**. In the illustrated embodiment, the first and second gate electrodes **124c** and **124d** are disposed on opposing sides of the pixel PX.

The storage electrode lines **131a** are supplied with a predetermined voltage and extend substantially in a transverse direction, the first direction, substantially parallel to the gate line **121**.

Each storage electrode line **131a** is disposed between two adjacent gate lines **121**, and nearly equidistant from the two adjacent gate lines **121**. Each storage electrode line **131a** includes a plurality of storage electrodes **137a** expanding upward and downward, towards the gate line **121** to which the pixel PX is connected and towards a gate line adjacent the pixel PX but not connected to the pixel PX. A plurality of bar-shaped extensions **139a** extends longitudinally downward from the storage electrodes **137a**, towards the gate line **121** to which the pixel PX is connected.

The storage electrodes **137a** are substantially rectangular-shaped to be symmetrical to the storage electrode lines **131a** and the extensions **139a** extend to near the first gate electrodes **124c**. While particular shapes and arrangements are illustrated, in alternative embodiments, the storage electrode lines **131a** as well as the storage electrodes **137a** and extensions **139a** may have various shapes and arrangements.

A gate insulating layer **140** preferably made of, but not limited to, silicon nitride (SiNx) or silicon oxide (SiOx) is

formed on the gate lines **121** and the storage electrode lines **131a**, as well as on exposed portion of the insulating substrate **110**.

A plurality of semiconductor islands **154c**, **154d**, **156b**, **157b** preferably made of hydrogenated a-Si or polysilicon are formed on the gate insulating layer **140**. The semiconductor islands **154c** and **154d** are disposed on the gate electrodes **124c** and **124d**, respectively. The semiconductor islands **156b** and **157b** cover edges of the gate lines **121** and the storage electrode lines **131a**.

A plurality of pairs of ohmic contact islands **163c**, **163d**, **165c**, **165d**, **166b**, and **167b** are formed on the semiconductor islands **154c**, **154d**, **156b**, and **157b**. The ohmic contacts **163c**, **163d**, **165c**, **165d**, **166b**, and **167b** are preferably made of n+ hydrogenated a-Si heavily doped with an n-type impurity such as phosphorous, or they may be made of silicide. A pair of the first ohmic contacts **163c** and **163d** and a pair of the second ohmic contacts **165c** and **165d** are placed on the semiconductors **154c** and **154d**, respectively, and are spaced from each other forming a channel on the semiconductors **154c** and **154d**. The ohmic contacts **166b** and **167b** are placed on the semiconductors **156b** and **157b**, respectively.

A plurality of data lines **171a** and **171b** and a plurality of pairs of first and second drain electrodes **175c** and **175d** are formed on the ohmic contacts **163c**, **163d**, **165c**, **165d**, **166b**, and **167b** and the gate insulating layer **140**.

The data lines **171a** and **171b** transmit data signals and extend substantially in the longitudinal direction, the second direction, to intersect the gate lines **121** and the storage electrode lines **131a**. Each data line **171a** and **171b** includes a plurality of source electrodes **173c** and **173d** projecting toward the gate electrodes **124c** and **124d**, respectively, and end portions **179a** and **179b** having a large area for contact with another layer or an external driving circuit, such as the data driver **501**.

The first and second drain electrodes **175c** and **175d** are separated from each other and from the data lines **171a** and **171b**.

Each of the first and second drain electrodes **175c** and **175d** includes expansions **177c** and **177d** overlapping the storage electrode **137a** and having a rectangular-shaped large area, bar-shaped end portions **176c** and **176d** opposite to the expansions **177c** and **177d** and facing the source electrodes **173c** and **173d** with respect to the first gate electrodes **124c** and **124d**, and connections **176cc** and **176dd** connecting the expansions **177c** and **177d** to the end portions **176c** and **176d**, respectively.

The expansions **177c** and **177d** overlap the storage electrode **137a** and the end portions **176c** and **176d** overlap the gate electrodes **124c** and **124d** and are partly enclosed by the source electrodes **173c** and **173d** that are curved like the character U, respectively. The connection **176cc** of the first drain electrode **175c** is mainly disposed on the extension **139a** to extend parallel thereto and is disposed within a vertical boundary thereof, such that the extension **139a** has a greater width than a width of the connection **176cc**. The area of the expansion **177d** of the second drain electrode **175d** is smaller than the area of the expansion **177c** of the first drain electrode **175c**.

The first/second gate electrodes **124c/124d**, the first/second source electrodes **173c/173d**, and the first/second drain electrodes **175c/175d** along with the semiconductors **154c/154d** form first/second TFTs Qc/Qd having channels formed in the semiconductor islands **154c/154d** disposed between the source electrodes **173c/173d** and the drain electrodes **175c/175d**, respectively.

The ohmic contacts **163c**, **163d**, **165c**, **165d**, **166b**, and **167b** are interposed only between the underlying semiconductors **154c**, **154d**, **156b**, and **157b** and the overlying data lines **171a** and **171b** and drain electrodes **175c** and **175d** thereon and reduce the contact resistance therebetween. The semiconductor islands **154c** and **154d** include some exposed portions, which are not covered with the data lines **171a** and **171b** and the drain electrodes **175a** and **175b**, such as portions located between the source electrodes **173c** and **173d** and the drain electrodes **175c** and **175d**, and between the ohmic contacts **163c**, **163d**, and **165c**, **165d**, respectively. The semiconductors **156b** and **157b** smooth the profile of the surface of the gate lines **121** and the storage electrode lines **131a**, thereby preventing disconnection of the data lines **171a** and **171b** and the drain electrodes **175c** and **175d**.

A passivation layer **180** is formed on the data lines **171a** and **171b** and the drain electrodes **175c** and **175d**, and on the exposed portions of the semiconductor islands **154c** and **154d**, as well as on the exposed portions of the gate insulating layer **140**.

The passivation layer **180** has a plurality of contact holes **185c**, **185d**, **182a**, and **182b** exposing the expansions **177c** and **177d** of the drain electrodes **175c** and **175d**, and the end portions **179a** and **179b** of the data lines **171a** and **171b**, respectively. The passivation layer **180** and the gate insulating layer **140** have a plurality of contact holes **181** exposing the end portions **129** of the gate lines **121**.

A plurality of pixel electrodes **191** having first and second sub-pixel electrodes **191a** and **191b**, a shield electrode **88b**, and a plurality of contact assistants **81**, **82a**, and **82b** are formed on the passivation layer **180**.

A pair of sub-pixel electrodes **191a** and **191b** forming a pixel electrode **191** engage with each other with respect to a gap **93**, and the outer boundary of the pixel electrode **191** has a substantially rectangular shape. The second sub-pixel electrode **191b** is approximately a rotated equilateral trapezoid, the base thereof being dented, such as at an area corresponding to the storage electrode line **131a**, and is mainly surrounded by the first sub-pixel electrode **191a**. The first sub-pixel electrode **191a** has an upper trapezoid, a lower trapezoid, and a center trapezoid connected to each other at a left side.

The center trapezoid of the first sub-pixel electrode **191a** is fitted into the dented base of the second sub-pixel electrode **191b**.

The gap **93** between the first sub-pixel electrode **191a** and the second sub-pixel electrode **191b** has approximately a uniform width and includes two pairs of upper and lower oblique portions, and three longitudinal portions having substantially uniform widths. For explanatory convenience, the gap **93** will also be referred to as a cutout.

The first sub-pixel electrode **191a** has cutouts **96a**, **96b**, **97a**, and **97b** extending from the top side of the upper trapezoid and the bottom side of the lower trapezoid to each right side thereof, respectively. The first sub-pixel electrode **191a** also includes cutouts **91** and **92a** which include a transverse portion and a pair of oblique portions connected thereto. The transverse portion extends shortly along an imaginary center transverse line of the first sub-pixel electrode **191a**, and the oblique portions make an angle of about 45 degrees with the storage electrode line **131a**. The second sub-pixel electrode **191b** has cutouts **94a** and **94b** extending from the left side to the right side of the pixel electrode **191**. The cutouts **91**, **92a**, **94a**, **94b**, **96a**, **96b**, **97a**, and **97b** substantially have inversion symmetry with respect to the storage electrode line **131a**. The cutouts **91**, **92a**, **94a**, **94b**, **96a**, **96b**, **97a**, and **97b** make an angle of about 45 degrees with respect to the gate line **121**,

and the cutouts on an upper portion of the pixel electrode **191** extend substantially perpendicular to the cutouts on a lower portion of the pixel electrode **191**.

The upper half and the lower half of the pixel electrode **191** are partitioned into eight partitions by the cutouts **91** to **97b**, respectively.

The first/second sub-pixel electrodes **191a/191b** are physically and electrically connected to the first/second drain electrodes **175c** and **175d** through the contact holes **185c** and **185d** such that the first and second sub-pixel electrodes **191a** and **191b** receive data voltages from the first/second drain electrodes **175c/175d** via the expansions **177c/177d**, respectively. A pair of the sub-pixel electrodes **191a** and **191b** is supplied with different predetermined data voltages based on an input image signal, respectively, and the magnitudes of the data voltages may be determined depending upon the sizes and shape of the sub-pixel electrodes **191a** and **191b**. Furthermore, the areas of the sub-pixel electrodes **191a** and **191b** may differ from each other. For instance, the second sub-pixel electrode **191b** receives a voltage that is higher than that of the first sub-pixel electrode **191a**, and is smaller in area than the first sub-pixel electrode **191a**.

The sub-pixel electrodes **191a** and **191b** supplied with the data voltages and the common electrode **270** of the common electrode panel **200** supplied with a common voltage form first and second LC capacitors  $C_{LCc}$  and  $C_{LCd}$ , which store applied voltages after the TFT turns off. Each of the LC capacitors  $C_{LCc}$  and  $C_{LCd}$  includes the LC layer **3** as a dielectric.

The first and second sub-pixel electrodes **191a** and **191b** and the expansions **177c** and **177d** connected thereto overlap a storage electrode line **131a** including a storage electrode **137a** and an extension **139a**. The first and second sub-pixel electrodes **191a** and **191b** and the expansions **177c** and **177d** connected thereto and the storage electrode line **131a** form additional storage capacitors  $C_{STc}$  and  $C_{STd}$ , which enhance the voltage storing capacity of the LC capacitors  $C_{LCc}$  and  $C_{LCd}$ , respectively.

The shielding electrode **88b** is supplied with the common voltage, and it includes longitudinal portions extending along the data lines **171a** and **171b** and transverse portions extending along the gate lines **121**. The longitudinal portions fully cover the data lines **171a** and **171b**, and the transverse portions fully cover the gate lines **121** and connect adjacent longitudinal portions. The shielding electrode **88b** blocks electric fields generated between the data lines **171a** and **171b** and the pixel electrodes **191** and between the data lines **171a** and **171b** and the common electrode **270** to reduce distortion of the voltage of the pixel electrode **191** and signal delay of the data voltages transmitted by the data lines **171a** and **171b**.

The contact assistants **81**, **82a**, and **82b** are connected to the end portions **129** of the gate lines **121** and the end portions **179a** and **179b** of the data lines **171a** and **171b** through the contact holes **181**, **182a**, and **182b**, respectively. The contact assistants **81**, **82a**, and **82b** protect the end portions **129**, **179a**, and **179b** and enhance the adhesion between the end portions **129**, **179a**, and **179b** and external devices.

A description of the common electrode panel **201** follows. A light blocking member **220**, a plurality of color filters **230**, an overcoat **250**, and a common electrode **270** are sequentially formed on an insulating substrate **210** made of a material such as, but not limited to, transparent glass or plastic.

The common electrode **270** has a plurality of sets of cutouts **71**, **72**, **73a**, **74a**, **75c**, **75d**, **76c**, **76d**, **77a**, **77b**, **78a**, and **78b**.

A set of cutouts **71** to **78b** face a pixel electrode **191** and include center cutouts **71**, **72**, **73a**, and **74a**, upper cutouts **75c**, **76c**, **77a**, **78a**, and lower cutouts **75d**, **76d**, **77b**, **78b**.

Each of the cutouts **71** to **78b** is disposed on the common electrode **270** with respect to a center of the left edge of the pixel electrode **191**, with respect to a location between adjacent cutouts **91** to **97b** of the pixel electrode **191**, or with respect to a location between a cutout **97a** or **97b** and a chamfered edge of the pixel electrode **191**. In addition, each of the cutouts **72** to **78b** has at least an oblique portion extending parallel to the cutout **91** to **97b** of the pixel electrode **191**.

Each of the lower and the upper cutouts **75c** to **78b** includes an oblique portion, and a pair of transverse and longitudinal portions. The oblique portion extends along the common electrode **270** corresponding to approximately from a right edge to an upper edge or lower edge of the pixel electrodes **191**. The transverse and longitudinal portions extend from respective ends of the oblique portion along portions of the common electrode **270** corresponding to edges of the pixel electrode **191**, overlapping the edges of the pixel electrode **191**, and making obtuse angles with the oblique portion.

The center cutout **71** includes a longitudinal portion overlapping and extending the left edges thereof along portions of the common electrode **270** corresponding to left edges of the pixel electrode **191** and a transverse portion extending from the center of the longitudinal portion along portions of the common electrode **270** corresponding to the storage electrode line **131a**.

Each of the center cutouts **72** and **73a** includes a central transverse portion, a pair of oblique portions, and a pair of terminal longitudinal portions. The central transverse portion extends on the common electrode **270** corresponding to approximately from a center or the right edge of the pixel electrode **191a** along the storage electrode line **131**. The oblique portions extend from an end of the central transverse portion approximately to a portion of the common electrode **270** corresponding to the left edge of the pixel electrode **191** and make oblique angles with the storage electrode line **131a**. The terminal longitudinal portions extend from the ends of the respective oblique portions along portions of the common electrode **270** corresponding to the left edge of the pixel electrode **191**, overlapping the left edge of the pixel electrode **191**, and making obtuse angles with the respective oblique portions.

The center cutout **74a** includes a longitudinal portion, a pair of oblique portions, and a terminal longitudinal portion. The longitudinal portion extends along portions of the common electrode **270** corresponding to the right edge of the pixel electrode **191**, overlapping the left edge of the pixel electrode **191**.

The oblique portions extend from an end of the longitudinal portion approximately to portions of the common electrode **270** corresponding to the left edge of the pixel electrode **191**. The terminal longitudinal portions extend from the ends of the respective oblique portions along portions of the common electrode **270** corresponding to the left edge of the pixel electrode **191**, overlapping the left edge of the pixel electrode **191**, and making obtuse angles with the respective oblique portions.

The oblique portions of the cutouts **72** to **77b** include triangular-shaped notches. Alternatively, the notches may be formed in the shape of a rectangle, a trapezoid, or a semi-circle, or they may be concave or convex.

Alignment layers **11** and **21** are coated on inner surfaces of the panels **101** and **201**, and polarizers **12** and **22** are provided on outer surfaces of the panels **101** and **201**.

The display operations of the LCD according this embodiment of the present invention may be substantially the same as those of the LCDs shown in FIGS. **1A** to **1C**, and a description of the display operations is therefore omitted.

As will be further described below, the magnitudes of the kickback voltages  $V_{kc}$  and  $V_{kd}$  of the first and second sub-pixels **PXc** and **PXd** of the LCD according to this exemplary embodiment of the present invention are substantially equal to each other.

The capacitance of the LC capacitors  $C_{LCc}$  and  $C_{LCd}$  of the first and second sub-pixel **PXc** and **PXd** is defined by the areas of the first and second sub-pixel electrodes **191a** and **191b**. For example, the first sub-pixel electrode **191a** may have a larger area than the second sub-pixel electrode **191b**. Therefore, when the magnitudes of the voltages applied to the first and second sub-pixel electrodes **191a** and **191b** are substantially equal to each other, the capacitance of the first LC capacitor  $C_{LCc}$  is larger than that of the second LC capacitor  $C_{LCd}$ . In addition, the area of the expansion **177c** of the first drain electrode **175c** overlapping the storage electrode **137a** is larger than the area of the expansion **177d** of the second drain electrode **175d**. However, the first LC capacitor  $C_{LCc}$  of the first sub-pixel electrode **191a** mostly operating at low grays has a lower dielectric constant that is defined by the orientation of the LC molecules than that of the second LC capacitor  $C_{LCd}$  of the second sub-pixel electrode **191b** mostly operating at upper grays, so that the capacitance of the first LC capacitor  $C_{LCc}$  is decreased and the capacitance of the second LC capacitor  $C_{LCd}$  is increased.

Accordingly, when the capacitance of the LC capacitors  $C_{LCc}$  and  $C_{LCd}$  of the first and second sub-pixel electrodes **191a** and **191b** is fixed, the magnitude of the kickback voltage  $V_{kc}$  of the first sub-pixel electrode **191a** is larger than the magnitude of the kickback voltage  $V_{kd}$  of the second sub-pixel electrode **191b**. As a result, for equilibrating the kickback voltages  $V_{kc}$  and  $V_{kd}$ , the capacitance of the first and second storage capacitors  $C_{STc}$  and  $C_{STd}$  should be adjusted.

To increase the capacitance of the storage capacitor  $C_{STc}$  for preventing increments of the kickback voltage  $V_{kc}$ , the extensions **139a** of the storage electrode **137a** that is overlapped by the connection **176cc** of the first drain electrode **175c** should be further formed or the vertical width of the expansion **177c** of the first drain electrode **175c** and the storage electrode **137a** overlapped by the expansion **177c** should be enlarged. Since the magnitudes of the kickback voltages  $V_{kc}$  and  $V_{kd}$  of the first and second sub-pixels **PXc** and **PXd** are substantially equal to each other, the optimal magnitude of the common voltage  $V_{com}$  is defined and the kickback voltages  $V_{kc}$  and  $V_{kd}$  also equilibrate, and thereby a flicker phenomenon is prevented.

As shown in FIGS. **11** and **12**, the storage capacitor  $C_{STc}$  is further formed by the extension **139a** of the storage electrode **137a** overlapped by the connection **176cc** of the first drain electrode **175c**, so that sufficient storage capacitance of the storage capacitors is ensured even though the area of the storage electrode **137a** is decreased and the aperture ratio is also increased since the area of the storage electrode **137a** overlapped by the expansion **177c** need not be enlarged.

In addition, the widths of the expansion **177d** disposed at a right portion of the pixel **PX** of the second drain electrode **175d** and the portion of the storage electrode **137a** overlapped by the expansion **177d** may become more narrow, thereby further decreasing the capacitance of the storage capacitor  $C_{STd}$ . Therefore, on application of a voltage to the second sub-pixel electrode **191b**, which is larger than that applied to the first sub-pixel electrode **191a**, the decrease of the kickback voltage  $V_{kd}$  is compensated, thereby preventing the flicker phenomenon and the decrease of the aperture ratio.

Various characteristics based on the TFT array panel shown in FIGS. **1** to **8** may be applied to the TFT array panel shown in FIGS. **9** to **12**.

Referring to FIGS. 13A and 13B, an exemplary LCD according to another exemplary embodiment of the present invention will be described.

FIG. 13A is a layout view of an exemplary TFT array panel for an exemplary LCD according to an exemplary embodiment of the present invention, and FIG. 13B is a sectional view of the exemplary TFT array panel shown in FIG. 13A taken along line XIII B-XIII B.

A plurality of gate lines 121 and a plurality of storage electrode lines 131b are formed on an insulating substrate 110 made of a material such as, but not limited to, transparent glass or plastic.

The gate lines 121 transmit gate signals and extend substantially in a transverse direction, the first direction. Each of the gate lines 121 includes a plurality of gate electrodes 124e projecting upward towards the pixel to which it is connected and an end portion 129 having a large area for contact with another layer or an external driving circuit, such as a gate driver, and arranged at the left side thereof, although the end portion 129 may be alternatively arranged at the right side thereof.

The storage electrode lines 131b are supplied with a predetermined voltage and extend substantially in a transverse direction, the first direction, and substantially parallel to the gate lines 121.

Each storage electrode line 131b is disposed between two adjacent gate lines 121 and is positioned nearly equidistant from two adjacent gate lines 121. Each storage electrode line 131b includes a plurality of storage electrodes 137b expanding upward and downward towards the gate line 121 and towards the adjacent gate line 121, and a plurality of bar-shaped extensions 139b longitudinally extending downward toward the gate line 121 from the storage electrodes 137b.

The storage electrodes 137b are substantially rectangular-shaped to be symmetrical to the storage electrode lines 131b, and the extensions 139b extend to near the gate electrodes 124e.

While particular shapes and arrangements are illustrated, the storage electrode lines 131b as well as the storage electrodes 137b and extensions 139b may have various shapes and arrangements within the scope of these embodiments.

A gate insulating layer 140, preferably made of, but not limited to, silicon nitride (SiN<sub>x</sub>) or silicon oxide (SiO<sub>x</sub>), is formed on the gate lines 121 and the storage electrode lines 131b, and may be further formed on exposed portions of the insulating substrate 110.

A plurality of semiconductor islands 154e preferably made of hydrogenated a-Si or polysilicon are formed on the gate insulating layer 140. The semiconductor islands 154e are disposed on the gate electrodes 124e.

The semiconductor islands 154e extend to the boundary of the gate lines 121, and may be disposed on the boundary of the storage electrode lines 131b.

A plurality of pairs of ohmic contact islands 163e and 165e are formed on the semiconductor islands 154e.

A plurality of data lines 171 and a plurality of drain electrodes 175e are formed on the ohmic contacts 163e and 165e and the gate insulating layer 140.

The data lines 171 transmit data signals and extend substantially in the longitudinal direction, the second direction, to intersect the gate lines 121 and the storage electrode lines 131b. Each data line 171 includes a plurality of source electrodes 173e projecting toward and overlapping the gate electrodes 124e, and an end portion 179 having a large area for contact with another layer or an external driving circuit, such as the data driver.

Each of the drain electrodes 175e includes expansions 177e overlapping the storage electrode 137b and having a rectangular-shaped large area, bar-shaped end portions 176e facing the source electrodes 173e with respect to the gate electrodes 124e and opposite to the expansions 177e, and connections 176ee connecting the expansions 177e to the end portions 176e.

Each expansion 177e overlaps the storage electrode 137b, and each end portion 176e overlaps a gate electrode 124e and is partly enclosed by a source electrode 173e curved like a character U. The expansions 177e of the drain electrodes 175e are called "coupling electrodes."

Each connection 176ee of a drain electrode 175e is mainly disposed on an extension 139b to extend parallel to the extension 139b and disposed within a vertical boundary of the extension 139b, such that the connection 176ee has a smaller width than the extension 139b.

The gate electrodes 124e, the source electrodes 173e, and the drain electrodes 175e along with the semiconductors 154e form TFTs having channels formed on the semiconductor islands 154e disposed between the source electrodes 173e and the drain electrodes 175e, respectively.

The ohmic contacts 163e and 165e are interposed only between the underlying semiconductors 154e and the overlying data lines 171 and drain electrodes 175e thereon, and reduce the contact resistance therebetween. The semiconductor islands 154e include some exposed portions that are not covered with the data lines 171e and the drain electrodes 175e, such as portions located between the source electrodes 173e and the drain electrodes 175e, and between the ohmic contacts 163e and 165e, respectively, thus forming the channels of the TFTs. The semiconductors 154e may also smooth the profile of the surface of the gate lines 121, thereby preventing disconnection of the data lines 171.

A passivation layer 180 is formed on the data lines 171 and the drain electrodes 175e and the exposed portions of the semiconductor islands 154e. The passivation layer 180 may be further formed on exposed portions of the gate insulating layer 140.

The passivation layer 180 has a plurality of contact holes 182 and 185e exposing the end portions 179 of the data lines 171 and the coupling electrodes 177e, respectively. The passivation layer 180 and the gate insulating layer 140 have a plurality of contact holes 181 exposing the end portions 129 of the gate lines 121.

A plurality of pixel electrodes 191, a plurality of shield electrodes 88, and a plurality of contact assistants 81 and 82 are formed on the passivation layer 180.

Each pixel electrode 191 approximates a rectangle that has four chamfered corners. The chamfered corners of the pixel electrode 191 make an angle of about 45 degrees with respect to the gate lines 121. The pixel electrodes 191 overlap the gate lines 121, to increase the aperture ratio.

A pair of sub-pixel electrodes 191c and 191d forming a pixel electrode 191 engage with each other with respect to a gap 93.

The gap 93 includes a pair of upper and lower oblique portions and longitudinal portions. The upper and lower oblique portions extend from the left edge of the pixel electrode 191 to the right edge of the pixel electrode 191, and the longitudinal portions connect the upper and lower portions. The upper and lower oblique portions make an angle of about 45 degrees with respect to the gate lines 121.

The second sub-pixel electrode 191d is approximately a right angle-rotated equilateral trapezoid and the first sub-pixel electrode 191c includes a pair of trapezoids rotated to a right angle and a longitudinal portion facing the right edge of

the second sub-pixel electrode **191d**. The trapezoids of the first sub-pixel electrode **191c** face the oblique edges of the second sub-pixel electrode **191d**, respectively.

The first sub-pixel electrode **191c** has lower and upper cutouts **94a**, **94b**, **95a**, and **95b**. The lower and upper cutouts **94a** and **94b** extend from the bottom corner and the top corner of the first sub-pixel electrode **191c** to each right side thereof, respectively. The lower and upper cutouts **95a** and **95b** extend from the bottom side or the top side of the first sub-pixel electrode **191c** to each right side thereof, respectively. The lower and upper cutouts **94a**, **94b**, **95a**, and **95b** make an angle of about 45 degrees with respect to the gate line **121** and the lower cutouts **94a**, **95a** extend substantially perpendicular to the upper cutouts **94b**, **95b**.

The second sub-pixel electrode **191d** includes center cutouts **91** and **92**. The center cutout **91** has an inlet near the center portion of the left side of the second sub-pixel electrode **191d**, and the inlet of the cutout **91** has a pair of inclined edges substantially parallel to the upper oblique portion and the lower oblique portion of the gap **93**, respectively.

The cutout **92** has a transverse portion shortly extending in a transverse direction along the center of the storage electrode **137b**, and a pair of oblique portions extending approximately parallel to the upper oblique portion and lower oblique portion of the gap **93** from the transverse portions, respectively. For explanatory convenience, the gap **93** will be also referred to as a cutout.

Each of the pixel electrodes **191** are partitioned into six partitions by the cutouts **91** to **95b**, respectively. The cutouts **91** to **95b** substantially have inversion symmetry with respect to a storage electrode line **131b**.

While a particular arrangement is illustrated, the number of partitions or the number of cutouts may be varied in alternative embodiments depending on the design factors such as the size of pixels, the ratio of the transverse edges and the longitudinal edges of the pixel electrode **191**, the type and characteristics of the LC layer, and so on.

The polarizer **12** is provided on the outer surface of the panel **100**. The first sub-pixel electrodes **191c** are physically and electrically connected to the drain electrodes **175e** through the contact holes **185e** such that the first sub-pixel electrodes **191c** receive data voltages from the drain electrodes **175e** via the expansions or coupling electrodes **177e**, respectively.

The first and second sub-pixel electrodes **191c** and **191d** that are supplied with the data voltages and the common electrode (not shown) of the common electrode panel (not shown) that is supplied with a common voltage form first and second LC capacitors  $C_{LCe}$  and  $C_{LCf}$ , which store applied voltages after the TFT turns off.

The first sub-pixel electrodes **191c** and the coupling electrodes **177e** connected thereto overlap a storage electrode line **131b** including a storage electrode **137b**. The first sub-pixel electrodes **191c** and the coupling electrodes **177e** connected thereto as well as the connection **176ee** and the storage electrode line **131b** including the storage electrode **137b** and the extension **139b** form storage capacitors  $C_{STE}$  which enhance the voltage storing capacity of the first LC capacitors  $C_{LCe}$ .

The second sub-pixel electrodes **191d** overlap the coupling electrodes **177e**, to form coupling capacitors  $C_{cp}$ .

The TFT applies data voltages from a data line **171** to the first LC capacitor  $C_{LCe}$  and the coupling capacitor  $C_{cp}$  in response to a gate signal from a gate line **121**, and the coupling capacitor  $C_{cp}$  transmits the data voltage with a modified magnitude to the second LC capacitor  $C_{LCf}$ .

If the storage electrode line **131b** is supplied with the common voltage  $V_{com}$ , and each of the capacitors  $C_{LCe}$ ,

$C_{STE}$ ,  $C_{LCf}$ , and  $C_{cp}$  and the capacitance thereof are denoted as the same reference characters, the voltage  $V_f$  charged across the second LC capacitor  $C_{LCf}$  is given by:

$$V_f = V_e \times [C_{cp} / (C_{cp} + C_{LCf})],$$

where  $V_e$  denotes the voltage of the first LC capacitor  $C_{LCe}$ .

Since the term  $C_{cp} / (C_{cp} + C_{LCf})$  is smaller than 1, the voltage  $V_f$  of the second LC capacitor  $C_{LCf}$  is smaller than the voltage  $V_e$  of the first LC capacitor  $C_{LCe}$ . This inequality may also be true for a case in which the voltage of the storage electrode line **131b** is not equal to the common voltage  $V_{com}$ .

When the potential difference is generated across the first LC capacitor  $C_{LCe}$  or the second LC capacitor  $C_{LCf}$ , an electric field that is substantially perpendicular to the surfaces of the TFT array panel **100** and the common electrode panel (not shown) is generated in the LC layer (not shown).

Then, the LC molecules in the LC layer tilt in response to the electric field such that their long axes are perpendicular to the field direction. The degree of the tilt of the LC molecules determines the variation of the polarization of light incident on the LC layer, and the variation of the light polarization is transformed into the variation of the light transmittance by the polarizers **12**. In this way, the LCD displays images.

The tilt angle of the LC molecules depends on the strength of the electric field. Since the voltage  $V_e$  of the first LC capacitor  $C_{LCe}$  and the voltage  $V_f$  of the second LC capacitor  $C_{LCf}$  are different from each other, the tilt direction of the LC molecules in the first sub-pixel is different from that in the second sub-pixel, and thus the luminance of the two sub-pixels are different. Accordingly, to maintain the average luminance of the two sub-pixels within a target luminance, the voltages  $V_e$  and  $V_f$  of the first and second sub-pixels can be adjusted so that an image viewed from a lateral side is close to an image viewed from the front, thereby improving the lateral visibility.

The shielding electrode **88** is supplied with the common voltage, and it includes longitudinal portions extending along the data lines **171** and transverse portions extending along the gate lines **121**. The longitudinal portions fully cover the data lines **171**, and the transverse portions lie within the boundary of the gate lines **121**.

The contact assistants **81** and **82** are connected to the end portions **129** of the gate lines **121** and the end portions **179** of the data lines **171** through the contact holes **181** and **182**, respectively.

As shown in FIGS. **13A** and **13B**, the storage capacitor  $C_{STE}$  is further formed by the extension **139b** of the storage electrode **137b** overlapped by the connection **176ee** of the drain electrode **175e**, so that sufficient storage capacitance of the storage capacitor  $C_{STE}$  is ensured even though the area of the storage electrode **137b** is decreased, and the aperture ratio is also increased.

Various characteristics based on the TFT array panel shown in FIGS. **1** to **8** may be also applied to the TFT array panel shown in FIGS. **13A** and **13B**.

Next, an exemplary LCD according to another exemplary embodiment of the present invention will be described with reference to FIGS. **14A** and **14B**.

FIG. **14A** is a layout view of an exemplary TFT array panel for an exemplary LCD according to another exemplary embodiment of the present invention, and FIG. **14B** is a sectional view of the exemplary TFT array panel shown in FIG. **14A** taken along line XIVB-XIVB.

Referring to FIGS. **14A** and **14B**, layered structures of the exemplary TFT array panel of the exemplary LCD according

this exemplary embodiment are substantially the same as those shown in FIGS. 13A and 13B.

That is, a plurality of gate lines **121** including gate electrodes **124e** and end portions **129** and a plurality of storage electrode lines **131b** including storage electrodes **137b** and extensions **139b** are formed on an insulating substrate **110**. A gate insulating layer **140**, a plurality of semiconductor islands **154e**, and a plurality of ohmic contact islands **163e** and **165e** are sequentially formed on the gate lines **121** and the storage electrode lines **131b** and on exposed portions of the substrate **110**. A plurality of data lines **171** including source electrodes **173e** and end portions **179**, and a plurality of drain electrodes **175e** including expansions **177e**, end portions **176e**, and connections **176ee** are formed on the ohmic contacts **163e** and **165e** and the gate insulating layer **140**. A passivation layer **180** is formed on the data lines **171**, the drain electrodes **175e**, and the exposed portions of the semiconductors **154e**, as well as on exposed portions of the gate insulating layer **140**. A plurality of contact holes **181**, **182**, and **185** are provided at the passivation layer **180** and the gate insulating layer **140**. A plurality of pixel electrodes **191**, a plurality of shielding electrodes **88**, and a plurality of contact assistants **81** and **82** are formed on the passivation layer **180**. A polarizer **12** is provided on an outer surface of the TFT array panel **100**.

Differing from the TFT array panel shown in FIGS. 13A and 13B, each pixel electrode **191** is not partitioned into sub-pixel electrodes, and each pixel electrode **191** has center cutouts **91** and **92**, lower cutouts **93a**, **94a**, and **95a**, and upper cutouts **93b**, **94b**, and **95b**.

The lower and upper cutouts **93a**, **93b**, **94a**, and **94b** obliquely extend from the left edge of the pixel electrode **191** to the right edge of the pixel electrode **191**. The lower and upper cutouts **95a** and **95b** obliquely extend from the bottom side or the top side of the pixel electrode **191** to the right side of the pixel electrode **191**, respectively.

The lower and upper cutouts **93a**, **93b**, **94a**, **94b**, **95a**, and **95b** make an angle of about 45 degrees with respect to the gate line **121**, and the lower cutouts **93a**, **94a**, **95a** extend substantially perpendicular to the upper cutouts **93b**, **94b**, **95b**.

The center cutout **91** has an inlet near the center portion of the left side of the pixel electrode **191**, and the inlet of the cutout **91** has a pair of inclined edges that are substantially parallel to the lower and upper cutouts **93a** to **95b**, respectively. The cutout **92** has a transverse portion shortly extending in a transverse direction at the center of the storage electrode **137b**, and a pair of oblique portions extending approximately parallel to the upper and lower cutouts **93b**, **93a** from the transverse portions, respectively.

The pixel electrodes **191** are partitioned into a plurality of partitions by the cutouts **91** to **95b**, respectively. The cutouts **91** to **95b** substantially have inversion symmetry with respect to a storage electrode line **131b**.

The pixel electrodes **191** are physically and electrically connected to the drain electrodes **175e** through the contact holes **185** such that the pixel electrodes **191** receive data voltages from the drain electrodes **175e**.

The pixel electrodes **191** that are supplied with the data voltages and the common electrode (not shown) of the common electrode panel (not shown) that is supplied with a common voltage form LC capacitors  $C_{LCg}$ , which store applied voltages after the TFT turns off.

The pixel electrodes **191** and the expansions **177e** connected thereto overlap a storage electrode line **131b** including a storage electrode **137b**. The pixel electrodes **191** and the expansions **177e** connected thereto and the connections **176ee** and the storage electrode lines **131b** including the

storage electrodes **137b** and the extensions **139b** form storage capacitors  $C_{STg}$  which enhance the voltage storing capacity of the LC capacitors  $C_{LCg}$ .

The TFT applies data voltages from a data line **171** to the LC capacitor  $C_{LCg}$  in response to a gate signal from a gate line **121**. Then, the LC molecules in the LC layer tilt in response to the electric field such that their long axes are perpendicular to the field direction. The degree of the tilt of the LC molecules determines the variation of the polarization of light incident on the LC layer, and the variation of the light polarization is transformed into the variation of the light transmittance by the polarizers **12**. In this way, the LCD displays images.

The tilt directions of the LC molecules are determined by horizontal components of the electric field caused by distortion of the electric field generated by the oblique edges of the cutouts **91** to **95b** of the pixel electrodes **191** and cutouts (not shown) of the common electrode panel (not shown), and the horizontal components are perpendicular to edges of the cutouts **91** to **95b** and edges of the pixel electrodes **191**.

Referring to FIG. 14A, the tilt directions are generally four. Because the LC molecules have various tilt directions, the reference viewing angles of the LCD are increased.

While one exemplary embodiment is illustrated, the shapes and the arrangements of the cutouts **91** to **95b** may be modified in alternative embodiments. Also in alternative embodiments, at least one of the cutouts **91** to **95b** can be substituted with protrusions (not shown) or depressions (not shown). The protrusions are preferably made of an organic or inorganic material that is disposed on or under the pixel electrode **191** or the common electrode.

As shown in FIGS. 14A and 14B, the storage capacitor  $C_{STg}$  is further formed by the extension **139b** of the storage electrode **137b** overlapping the connection **176ee** of the drain electrode **175e**, so that even though the area of the storage electrode **137b** is decreased and sufficient storage capacitance of the storage capacitors  $C_{STg}$  is ensured, the aperture ratio is increased.

Various characteristics based on the TFT array panel shown in any of the previously described embodiments may be applied to the TFT array panel shown in FIGS. 14A and 14B.

Meanwhile, referring to FIGS. 4 to 7B, the characteristic that the storage capacitor  $C_{STa}$  is further formed by the extension **139** of the storage electrode **137** overlapping the connection **176aa** of the drain electrode **175a**, even though the area of the storage electrode **137** is decreased and the aperture ratio increases, is not limited to the above-described embodiments, but may also be used with various panels having a switching element or a plurality of switching elements.

In the present invention, in one exemplary embodiment thereof, one pixel electrode is partitioned into two sub-pixel electrodes that are supplied with different data voltages, so the lateral visibility is improved. In addition, by forming the extension of the storage electrode under the connection of the first drain electrode of the first sub-pixel electrode or adjusting the overlapping areas of the second drain electrode and the storage electrode, the capacitance of the storage capacitors is adjusted based on a capacitance variation of the LC capacitors that are supplied with the different data voltages. Accordingly, the kickback voltages of the two sub-pixel electrodes are equilibrated, and image deterioration such as the flicker phenomenon decreases. Furthermore, by forming the extension of the storage electrode under the connection of the drain electrode, sufficient storage capacitance is ensured and the aperture ratio also increases.

While the present invention has been described in detail with reference to exemplary embodiments, those skilled in the art will appreciate that various modifications and substitutions can be made thereto without departing from the spirit and scope of the present invention as set forth in the appended claims. 5

What is claimed is:

1. A liquid crystal display comprising:

a plurality of pixels arranged in the form of a matrix, each pixel having first and second sub-pixels; 10

a plurality of first signal lines connected to the first and second sub-pixels;

a plurality of second signal lines intersecting the first signal lines and connected to the first sub-pixels; and

a plurality of third signal lines intersecting the first signal lines and connected to the second sub-pixels, 15

wherein the first sub-pixels have first switching elements connected to the first and second signal lines, first liquid crystal capacitors connected to the first switching elements, and first storage capacitors connected to the first switching elements, 20

the second sub-pixels have second switching elements connected to the first and third signal lines, second liquid crystal capacitors connected to the second switching elements, and second storage capacitors connected to the second switching elements, 25

voltages applied to the first and second liquid crystal capacitors are obtained from image information,

the first sub-pixels are supplied with a voltage that is smaller than a voltage applied to the second sub-pixels with respect to a predetermined voltage, and 30

a storage capacitance of the first storage capacitors is larger than a first capacitance or a storage capacitance of the second storage capacitors is smaller than a second capacitance, where the first and second capacitances are capacitances of the first and second storage capacitors that cause kickback voltages of the first and second sub-pixels to be substantially equal to each other when the first and second sub-pixels are supplied with a same voltage. 35

2. The liquid crystal display of claim 1, wherein the first switching element comprises a first gate electrode and a first drain electrode, 40

the second switching element comprises a second gate electrode and a second drain electrode,

the first and second storage capacitors are separated from the first and second gate electrodes and commonly comprise a storage electrode having a body and an extension branched from the body,

the first storage capacitor is formed by overlapping the storage electrode and the first drain electrode,

the second storage capacitor is formed by overlapping the storage electrode and the second drain electrode,

the first liquid crystal capacitor comprises a first sub-pixel electrode connected to the first switching element, and the second liquid crystal capacitor comprises a second sub-pixel electrode connected to the second switching element.

3. The liquid crystal display of claim 2, wherein an area of the first sub-pixel electrode is larger than an area of the second sub-pixel electrode, and

an overlapping area of the storage electrode and the first drain electrode is larger than an overlapping area of the storage electrode and the second drain electrode.

4. The liquid crystal display of in: I claim 2, wherein the first drain electrode comprises an end portion overlapping the first gate electrode, an expansion overlapping the storage electrode and distanced from the end portion, and a connection connecting the end portion and the expansion, and

the body of the storage electrode is overlapped by the expansion of the first drain electrode and the second drain electrode, and the extension of the storage electrode is overlapped by the connection of the first drain electrode.

5. The liquid crystal display of claim 4, wherein a boundary of the expansion of the first drain electrode is disposed within a boundary of the body of the storage electrode, and a width of the extension of the storage electrode is wider than a width of the connection of the first drain electrode.

6. The liquid crystal display of claim 4, wherein a width of an overlapping portion of the body of the storage electrode and the second drain electrode is narrower than a width of an overlapping portion of the body of the storage electrode and the expansion of the first drain electrode.

\* \* \* \* \*

